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Design and Development of Scalable Solar Powered Water Purification Systems for Developing Nations

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DESIGN AND DEVELOPMENT OF SCALABLE SOLAR POWERED WATER PURIFICATION SYSTEMS FOR DEVELOPING NATIONS

By

Shavin Pinto

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Abstract

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This thesis presents the design and development of solar powered water purification systems. The systems were designed to meet specific customer requirements that were established from the experiences gained after the installation of five water purification systems in various Haitian communities. The systems are scalable and are able to supply 10,000-20,000 gallons of clean drinking water per day. The design consists of a three-stage filtration system with a disc-type sediment filter, a 0.1 micron ultrafiltration membrane, and an ultraviolet light for disinfection. The backwash cycle extends the life of the ultrafiltration membrane to 4 – 7 years before a new filter is required. Simplicity in operation was an important design consideration because it facilitates local operator training, and understanding. To ensure complete understanding of operation, a pictorial quick-start manual was developed so that operators only need to follow the diagrams laid out on the manual. The design folder with CAD drawings, schematics, datasheets, and troubleshooting guide are left with the local operators. Testing before shipping and after installation to ensure proper operation upon installation. On-site water quality testing ensures the system will promote improved community health.

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Chapter 1

Introduction

A Comprehensive approach is required to successfully provide communities in developing nations with sustainable water solutions. ERAU Project Haiti students have installed solar powered water purifiers in multiple Haitian communities since the devastating earthquake struck Port au Prince Haiti in 2010. With the experience gained over the years, ERAU Project Haiti has created a community development model demonstrating the key elements that make a humanitarian effort successful [1, 2]. Figure 1 summarizes the key elements of the community development model.

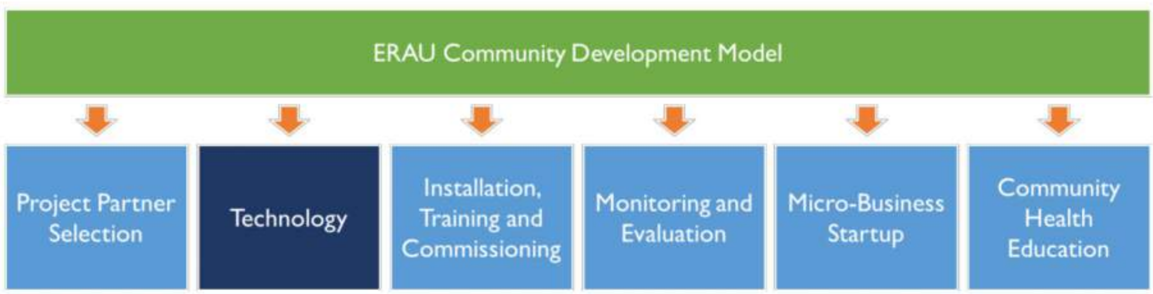


Figure 1: ERAU Community Development Model

It is the combination of all these elements that have made ERAU Project Haiti Successful over five years. The community development model is discussed in more detail in the work of Wong. Y 2014 [2]. This thesis discusses the highlighted element of the community development model, Technology. The key design features and technology that are critical to satisfy the water needs of developing nations in a sustainable manner are presented in detail.

1.1 Significance of the Study

Freshwater is the single most precious element for life on earth. It is essential for satisfying basic human needs, health, food production, energy and maintenance of regional and global ecosystems. Although 70 per cent of the earth's surface is covered by water, less than one percent of the freshwater resources are accessible for human use [3].

Improving access to clean drinking water and safe sanitation is one of the most effective means to improve health and well-being people globally. Approximately 1.1 billion people, which accounts for one sixth of the world population, lack access to safe fresh water sources and many more lack access to safe drinking water [3]. It is clear that clean water is often an access issue to a large portion of the population, and many waterborne diseases can bring considerable death. Water and hygiene related diseases like diarrhea claim 2 million lives each year, and also create 4 billion cases of illness [4]. This justifies the claim that no single type of intervention has greater overall impact on national development and public health than the allocation of resources for safe drinking water [5].

1.2 Thesis Statement

A community scale water purification system designed for developing nations must be simple yet effective. A simplistic design is critical so locals in the commissioned area can operate the system without extensive training. Furthermore, the system must be field serviceable with minimal operational costs and should not require frequent cartridge replacements. Since lack of power is common in developing nations the system should include a reliable power source for daily operations.

1.3 Limitations and Assumptions

The purification systems discussed in this thesis were designed for various Haitian communities through the funding obtained for ERAU Project Haiti. ERAU Project Haiti is a community development effort focused on post-earthquake Haiti. From a technology standpoint, Haiti installations provided field testing for design verification. The analysis was specific to Haiti but results are presented for developing nations generally. This is a reasonable assumption for two reasons. First, the design eliminates microbiological water borne pathogens which are common in many developing nations. Second, the vast majority of developing countries are also near the equator and therefore have ample sunlight for a solar power system.

1.4 List of Acronyms

AC	Alternating Current
CAD	Computer Aided Design
DC	Direct Current
EPA	Environmental Protection Agency
GPM	Gallons per Minute
MDGs	Millennium Development Goals
NOM	Natural Organic Matter
NSF	National Sanitation Foundation
NTU	Nephelometric Turbidity Units
PSI	Pounds per Square Inch
SEM	Scanning Electron Microscope
TMP	Transmembrane Pressure
UF	Ultrafiltration
UV	Ultraviolet
UN	United Nations
WASH	Water, Sanitation and Hygiene
WHO	World Health Foundation
Wh	Watt Hour

Chapter 2

Review of the Relevant Literature

2.1 Contaminants in Water

Both natural and human activities affect the chemical and biological characteristics of water, which ultimately affects human health. One of the most widespread and serious classes of water quality contaminants are due to microbiological pathogens such as bacteria, protozoa and viruses. These organisms are a leading global health hazard, especially in developing nations [6].

2.2 Common Waterborne Diseases in Developing Nations.

Consumption of unsafe water, inadequate sanitation and hygiene cause approximately 3.1 percent of all deaths worldwide and is also responsible for 3.7 percent of DALYs (disability adjusted life years) [7]. In developing nations, majority of health threats posed by poor water quality is the result of waterborne diseases caused by microbial contaminants. Waterborne diseases is one of the leading causes of death of children under the age of five. The annual number of deaths due to the consumption of unsafe water is higher than from all forms of violence, including war [7].

Typhoid and Cholera both remain a serious problem in many regions of the world. Diarrheal diseases caused by bacteria, parasites and viruses such as cholera, giardia, typhoid and rotavirus and E.coli pose serious threats to communities in developing nations. Approximately 1.8 million people die annually due to diarrheal diseases from which 88 percent are attributed to unsafe water supply and inadequate sanitation and hygiene [8]. Severe and repeated cases of diarrhea contribute extensively to childhood malnutrition, which is responsible for 35% of all deaths worldwide of children under the age of five [9].

Common non-diarrheal waterborne diseases such as Typhoid fever, causes 600,000 deaths each year. Hepatitis A and E are also common waterborne diseases caused by the ingestion of fecal contaminated water.

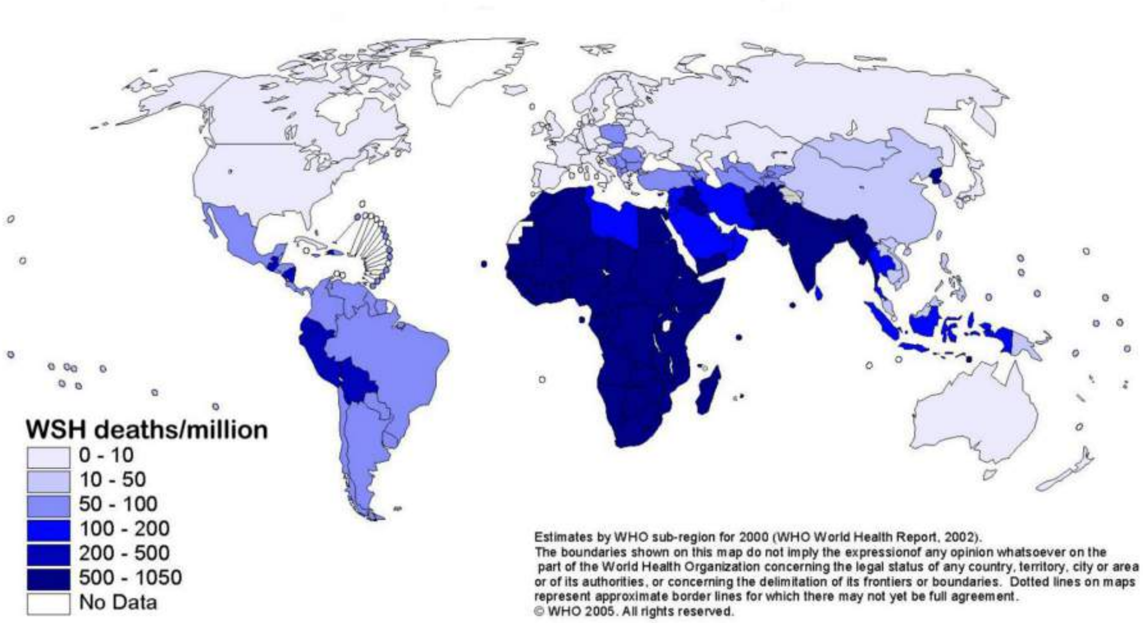


Figure 2: Deaths caused by lack of clean water and inadequate sanitation and hygiene practices[10]

There are various treatment methods for eliminating pathogens from water sources. However, finding the appropriate solution for a particular water supply involves the combination of treatment methods from a range of various processes [13].

2.3 EPA Microbiological Standards Water Purifiers

Table 1 illustrates the standards set by the EPA for purification systems that aim to reduce microbiological contaminants from water surface sources. By removing these categories of microbial contaminants, a purification system will achieve an EPA certification number.

Table 1 Contaminant removal levels for microbial filter systems [11]

Microbial Contaminant	Required Reduction Level
Bacteria	99.9999%
Virus	99.99%
Protozoa	99.90%
Turbidity	$\leq$1NTU

The purifier design presented here aims to meet or exceed these thresholds. Field testing presented in [1, 2, 36, 37, 45] provides qualitative results indicating safe water. Formal EPA certification tests have not been performed on the purification systems.

2.4 Membrane Filtration

Membrane filtration relies on the size exclusion mechanism as water is passed through a thin wall of porous material. Over the last decade, the use of membrane technology for water treatment have become very popular due to many advantages that the technology offers. Membrane filters are able to effectively remove contaminants without the addition of chemicals and have a relatively low energy consumption in comparison to conventional thermal separation processes such as distillation [12]. The ability of various membrane types to remove harmful water pathogens are illustrated in Figure 3. The figure demonstrates the size range water pathogens that needs to be removed from drinking water sources and the ability of different membrane types to remove each of these harmful pathogens through a size exclusion mechanism. Microfiltration(MF) and Ultrafiltration (UF) membrane filters in particular are commonly used in water treatment plants since these filters can be operated at relatively low pressure and can effectively eliminate harmful pathogens such as Cryptosporidium, and in the case of UF, a variety of viruses are also removed [13].

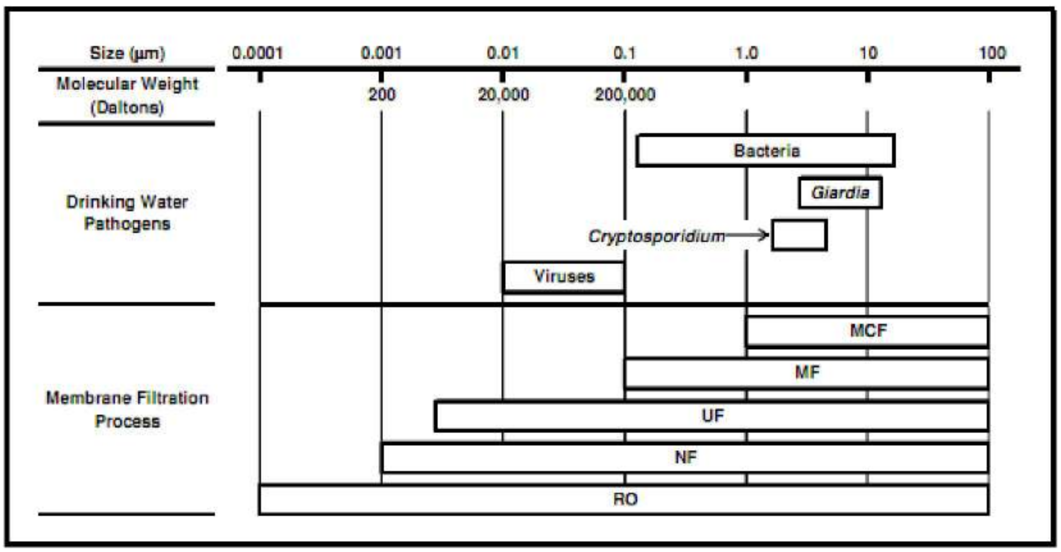
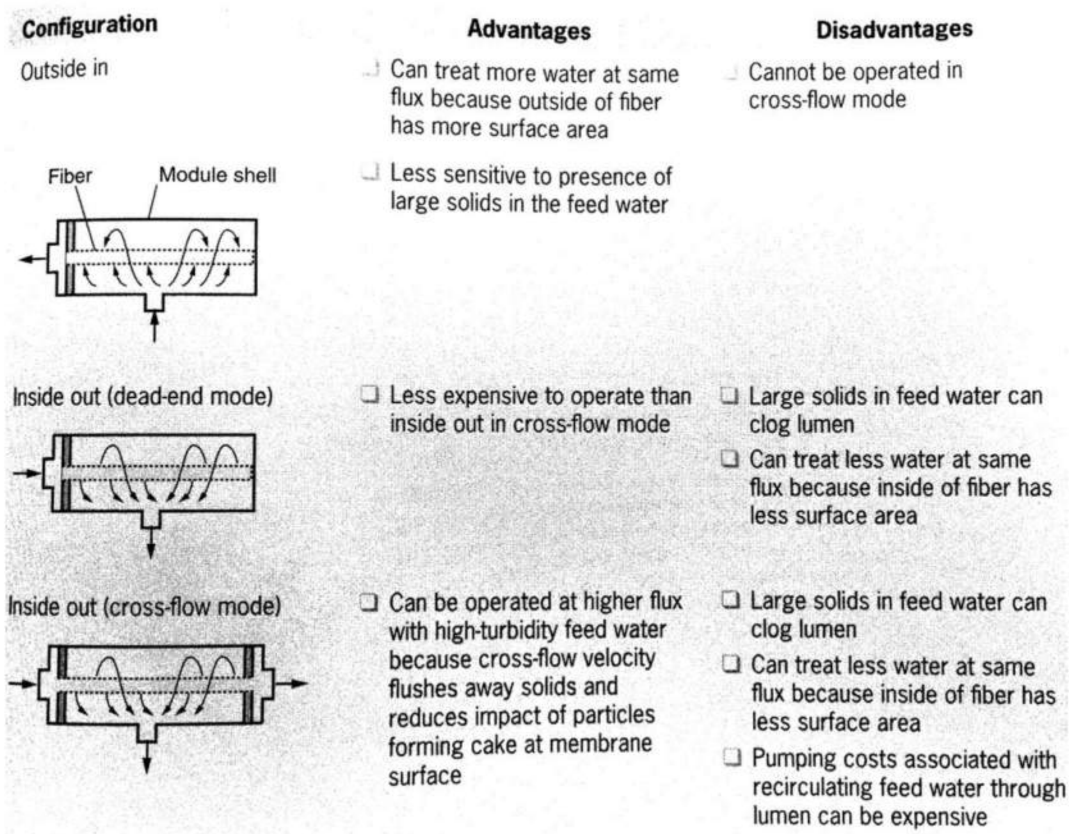


Figure 3: Filtration application guide for pathogen removal [12]

Figure 3 illustrates the different membrane classifications based on pore sizes. Membrane are also categorized as inside out or outside in and dead-end or cross-flow filtration. Figure 4 illustrates the different advantages and disadvantages of each membrane configuration. This design uses outside in membrane that filters using dead end filtration



Configuration	Advantages	Disadvantages
Outside in	❑ Can treat more water at same flux because outside of fiber has more surface area ❑ Less sensitive to presence of large solids in the feed water	❑ Cannot be operated in cross-flow mode
Inside out (dead-end mode)	❑ Less expensive to operate than inside out in cross-flow mode	❑ Large solids in feed water can clog lumen ❑ Can treat less water at same flux because inside of fiber has less surface area
Inside out (cross-flow mode)	❑ Can be operated at higher flux with high-turbidity feed water because cross-flow velocity flushes away solids and reduces impact of particles forming cake at membrane surface	❑ Large solids in feed water can clog lumen ❑ Can treat less water at same flux because inside of fiber has less surface area ❑ Pumping costs associated with recirculating feed water through lumen can be expensive

Figure 4: Membrane Configurations [10]

2.4.1 Hollow Fiber Ultrafiltration Membranes

Figure 5 illustrates the structure of hollow fiber membranes. A hollow fiber UF membrane cartridge consists of many hollow fibers illustrated in figure 5(A). The source water is forced through the porous membrane surface as shown in figure 5(B) and the filtered water is collected the center of the fiber known as the lumen [14].

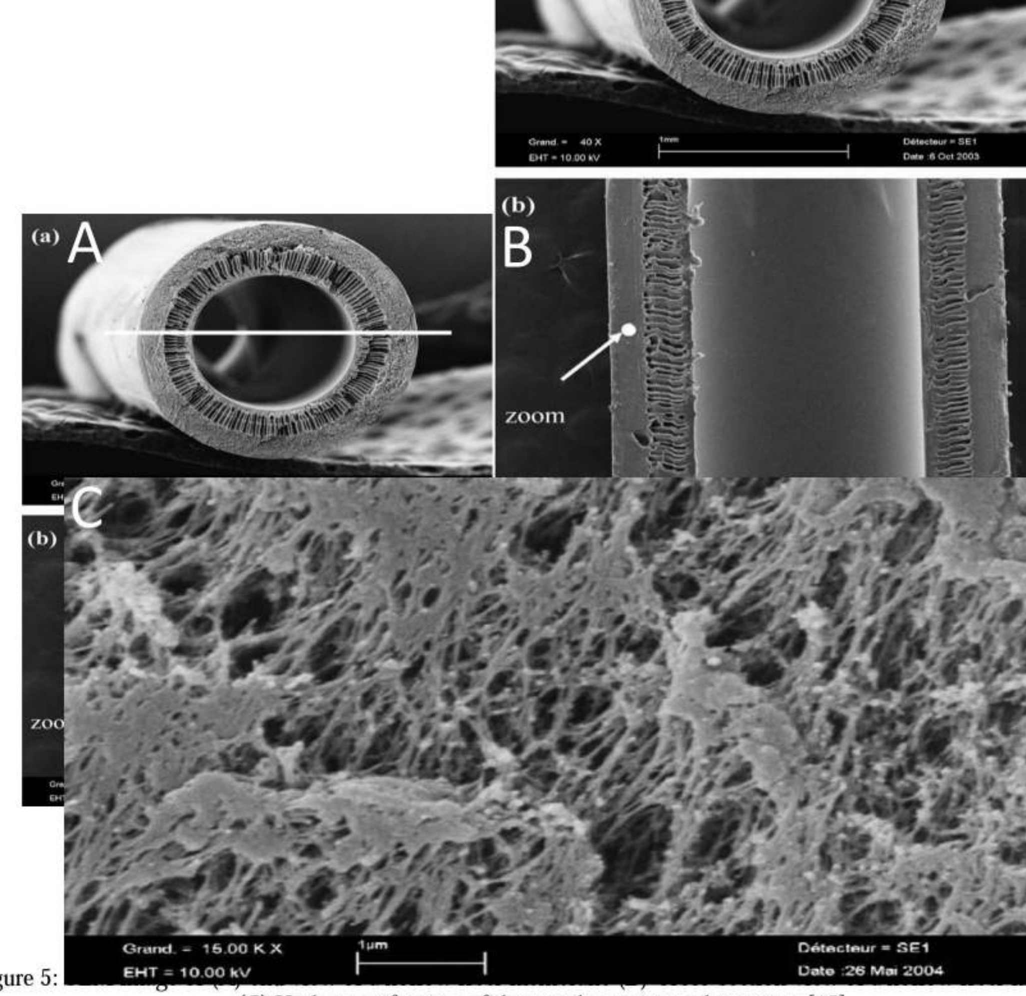


Figure 5: … embrane
(C) High magnification of the membrane internal structure [15]

The basic operating principle of membrane filtration is commonly described using the Darcy Equation:

$$J = \frac{Q}{a} = \frac{\Delta P}{\mu k_m}$$

Where:

J = Volumetric water flux through membrane

Q = Flow rate

a = Membrane area

ΔP = Transmembrane pressure across membrane

μ = Dynamic viscosity of water

k_m = Membrane resistance coefficient

A filter's volumetric water flux, J, is defined as flow rate per unit area. As solids accumulate on the membrane surface, the transmembrane pressure across the membrane increases causing a decline in volumetric water flux [16]. Membrane filters generally operate over a two stage cycle consisting of (1) filtration stage, during which particles accumulate and (2) backwash stage, where the accumulated particles are flushed from the system. Although backwashing the filter removes accumulated solids, a gradual and continuous flux decline is observed over a period of time. This gradual loss of performance, known as membrane fouling is due to clogging of the membrane surface that cannot be removed through backwash cycles. Therefore, membranes filters require chemical cleaning at proper intervals to enhance membrane performance and to avoid irreversible membrane fouling [12].

2.4.2 UF Membrane Fouling

A major limitation of membrane filtration systems is significant reduction of flux due to membrane fouling which occurs due to specific interactions between the membrane and constituents present in the source water. Membrane fouling is dependent various parameters such us characteristics of the source water, characteristics of the membrane, and hydraulic conditions of the purification system [15].

As illustrated in Figure 6, Membrane fouling is attributed to different mechanisms, including pore blockage/straining, organic matter adsorption and cake formation.

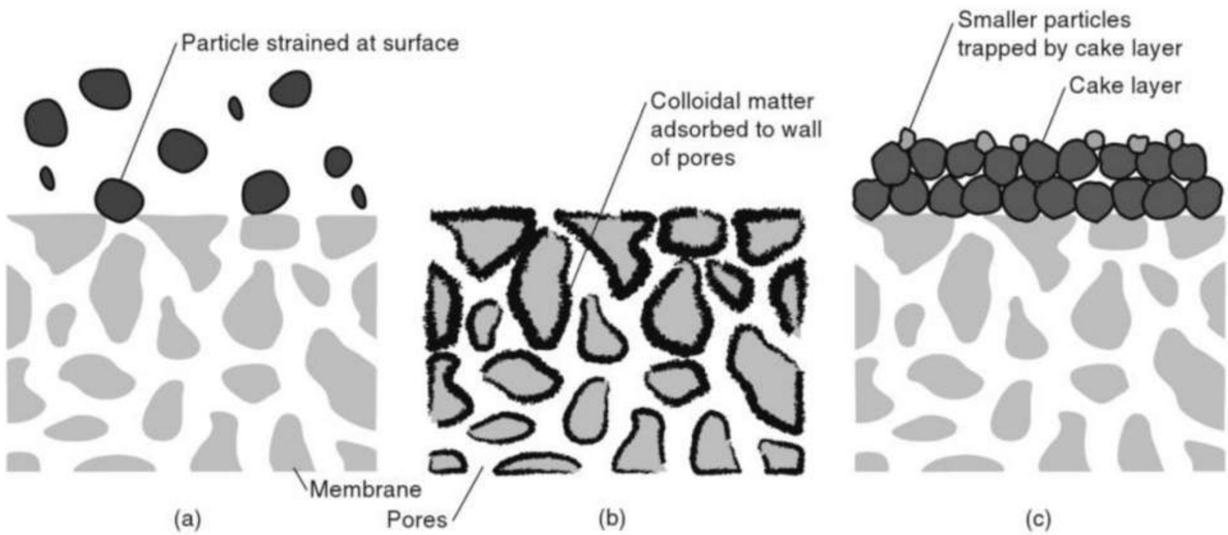


Figure 6: (a) Membrane straining (b) Organic matter absorption (c) Cake formation [10]

Straining is the most dominant filtration mechanism of membrane filtration. Particles larger than the membrane pore size are restricted at the surface while water and particles smaller than membrane pore size passes through [11].

Natural organic matter adsorbs to membrane surfaces and therefore soluble materials are sometime rejected even if their physical dimensions are smaller than the membrane pore size or retention rating [17]. The adsorption capacity of membranes however are quickly exhausted and there adsorption is not considered as an effective mechanism in long term operations of membrane filters.

Due to straining, a clean membrane accumulates a cake layer of solids over a filtration period. This cake layer acts as an additional filtration medium providing another mechanism for rejection. The cake layer is defined as a dynamic membrane as its filtering capacity varies over time [18]. As the cake layer thickens overtime, a significant drop in membrane flux is experienced and the cake layer is required to be removed through backwash cycles.

2.4.3 UF Membrane Backwash

To reduce the effects of fouling, usually a periodic hydraulic backwash procedure is employed. During this step, water flows backwards through the membrane and results in a partial removal of the deposited matter on the membrane surface [19]. Following a backwash, the membrane flux is restored to a certain extent, however, fouling is not always totally reversible by a backwash cycle alone. Some part of the deposited matter on the membrane surface and inside the pores cannot be removed, forming the irreversible part of fouling, which leads to the progressive deterioration of membrane performance [20].

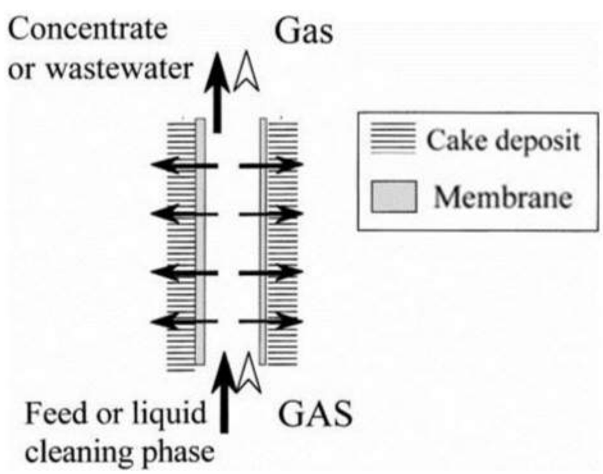
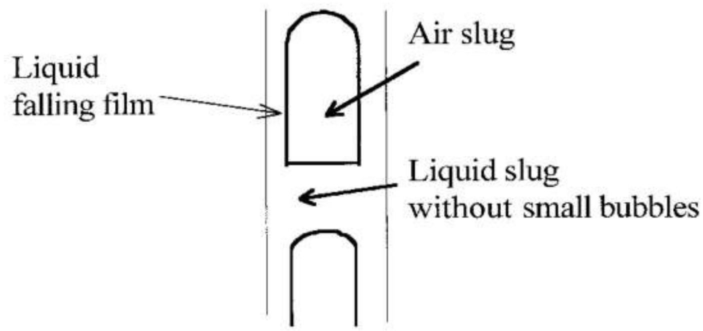


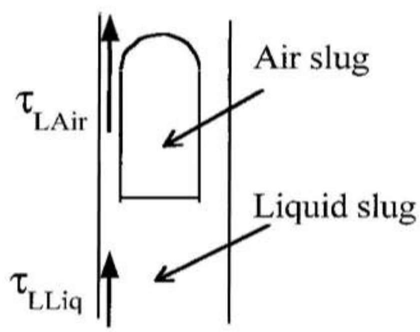
Figure 7: Concept of hollow fiber membrane backwash [20]

2.4.4 Air Sparging

During backwash, air is injected into the UF membrane to enhance backwash efficiency. When Air is injected into the ultrafiltration hollow fibers, it creates a gas-liquid mixture inside the filter. The influence of air leads to a slug flow consisting in a succession of air slugs and liquid slugs [22].



This leads to the generation of two different shear stresses, one induced by the liquid slugs (τ_{LLiq}) and another induced by the liquid film around the air slugs (τ_{LAir}).



A point located at the membrane wall experiences shear stresses of two different magnitudes, which induces an oscillating movement. Furthermore, this phenomenon creates turbulence near the membrane surface leading to flux enhancement [23].

2.4.5 Chemical Cleaning of Membrane Filtration

Membrane fouling is characterized as reversible or irreversible. The variation of specific flux over filtration time is illustrated in figure 8. A decline in specific flux is caused by an increase in TMP and over a period of time, the flux loss cannot be recovered through backwashing [24]. The specific flux generally continues to decrease during filtration runs, however, a significant amount can be recovered during backwashing.

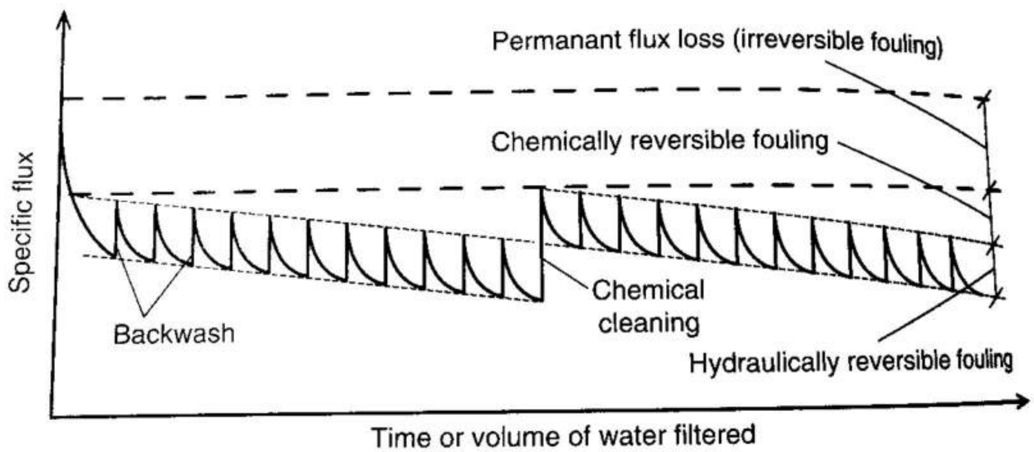


Figure 8: Variation of specific flux during filtration [11]

The flux that is recovered during backwash is defined as hydraulically reversible fouling [11]. Permanent flux loss is defined as irreversible fouling and is directly related to the quality of the source water that is being filtered and the type of the membrane used. The gradual decrease in specific flux loss over multiple filtration periods is due to the adsorption and clogging of materials within the membrane surface. These particles can be dissolved and removed by chemically cleaning the membranes leading to specific flux recovery [25].

Chemicals are used to break the bonds between the foulants and the membrane surface through enhancement of electrostatic repulsion by changing the pH values drastically.

Since this process essentially occurs through chemical reactions, the efficiency of chemical cleaning is highly dependent on the concentration of cleaning agents and the length of cleaning periods [26].

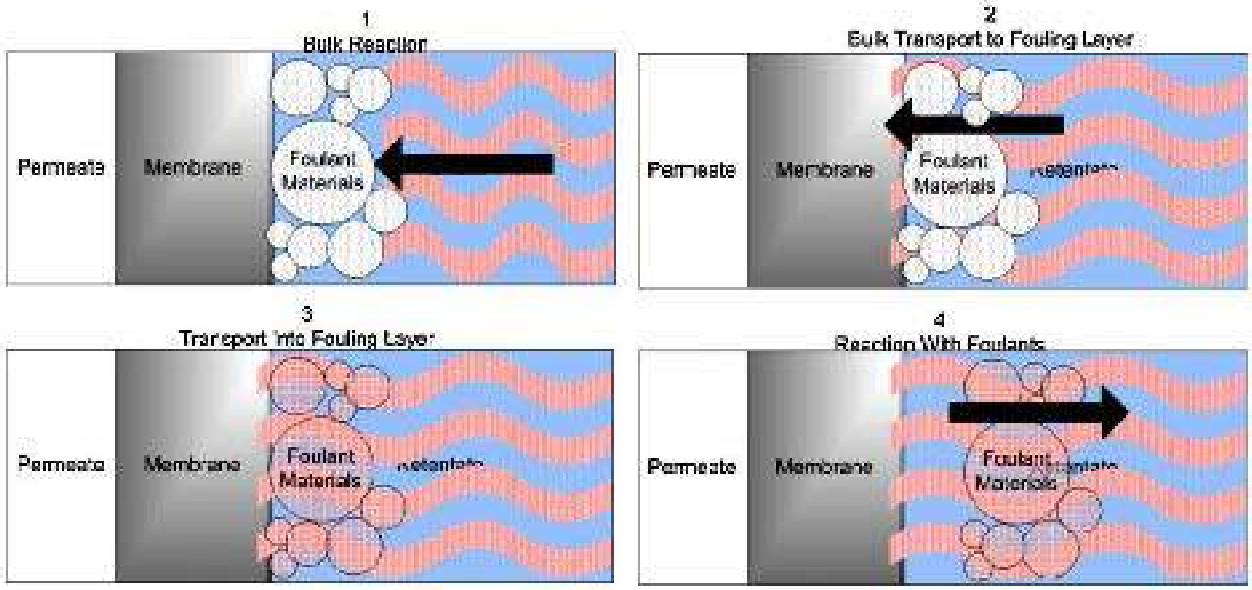


Figure 9: Electrostatic equilibrium model for membrane cleaning [27]

Use of Sodium Hydroxide and Oxidants

Sodium Hydroxide (NaOH), commonly known as caustic soda, is an effective chemical for cleaning membranes fouled by organic and microbial foulants. NaOH increases the solubility of solutes by hydrolysis and solubilization. Changes in molecule configuration leads to a loose fouling layer that allows easier access for chemicals to penetrate the inner portion of the fouling layer, which enhances the efficiency of cleaning [28]

Use of oxidants such as Sodium Hypochlorite (NaClO) increases the hydrophobicity of the membrane surfaces which reduces the adhesion of fouling materials to it [29].

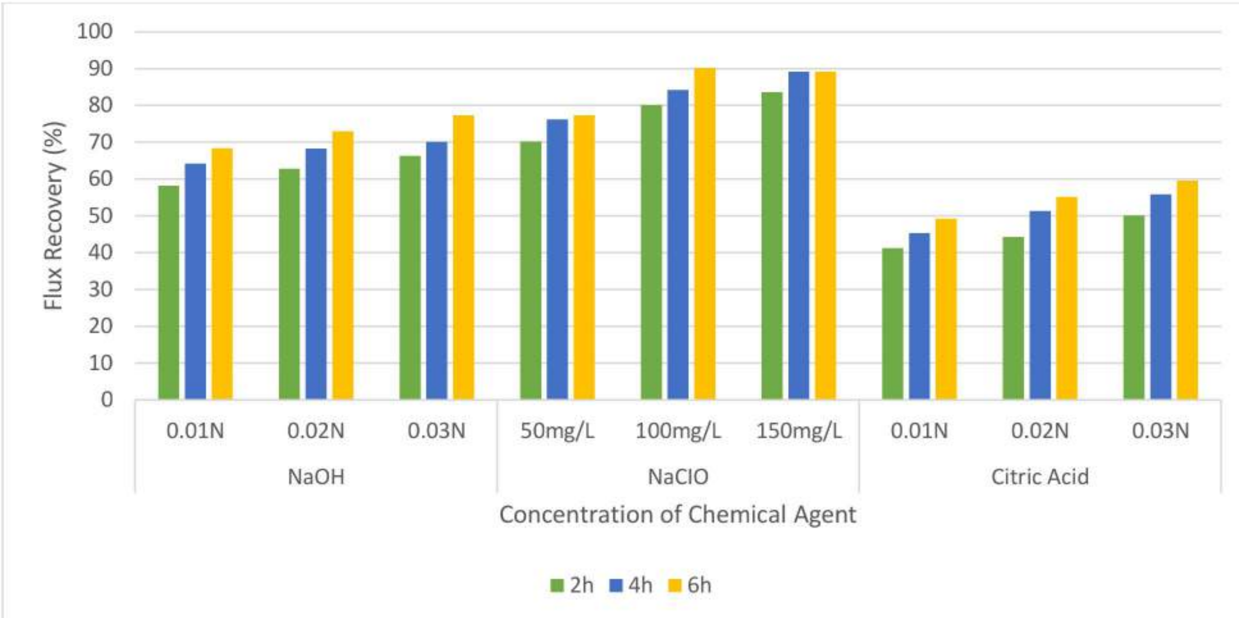


Figure 10: Percentage of flux recovered using various chemical agents [28]

The mixture of NaOH and NaClO is very efficient on fouling conditions dominated by natural organic matter (NOM). The fouling layer tends to have more open structure from NaOH and provides more access to NaClO to reach inner layer of fouling materials. The combination of NaOH and NaClO facilitates the mass transfer and reactions between chemicals and fouling materials, and therefore enhances the cleaning efficiency [27].

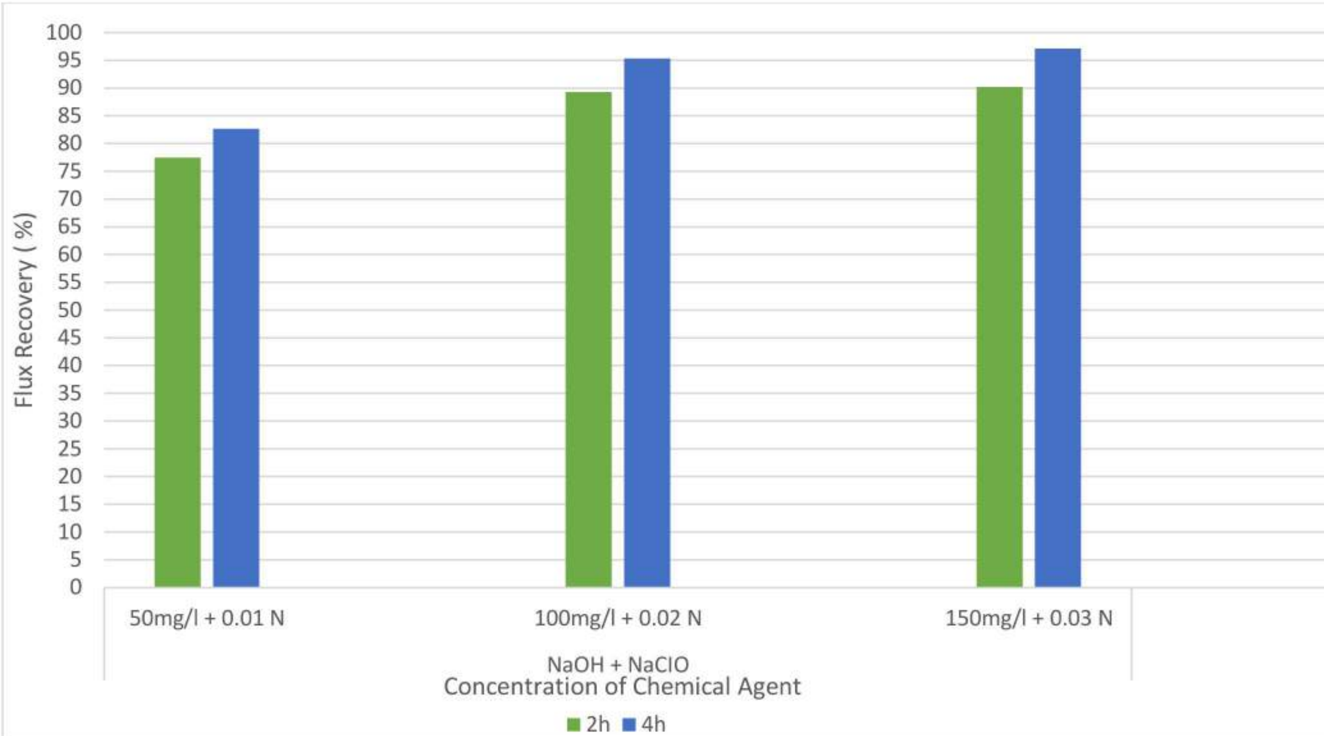


Figure 11: Percentage of flux recovered using NaOH + NaClO [28]

For this reason, household bleach (Clorox), which contains 3-8% sodium hypochlorite and 0.01-0.05% sodium hydroxide, is an effective chemical to utilize for cleaning membrane systems.

2.4 Disc and Screen Filters

Disc and screen filters are commonly used in micro irrigation systems. The water sources used for irrigation systems often high in particulates and as a result, filtration is essential to prevent emitters from being clogged [29].

In screen filters, particles are trapped on the surface of the filter which is made of a perforated material. Disc filters have many grooved discs pressed together, and the particles are trapped in between layers of discs. In both filter types, the particles larger than the pores of the filter media are retained and gradually the particles accumulate to from a cake layer, similar to membrane filters [30]. As suspended particles are trapped by the filters, the filtration rate decreases because the filter becomes clogged and must be cleaned to recover operational conditions. Most filters are cleaned with automatic backwashing based on either head loss across the filter or operation time intervals.

A study was conducted by University of Girona assessed the performance and backwashing efficiency of disc and screen filters in micro irrigation systems [30]. The disc filter (Arkal Filtration Systems) that was evaluated in the study is the same model used on the systems mentioned in this design thesis.

2.4.1 Water Consumption and Back Wash Efficiency

Filter backwashing requires additional clean water to flush out the trapped suspended particles from the filter surface [30].

The number of backwash cycles and manual cleanings that were performed during the experiment is illustrated in table 1. At certain it times, it was necessary to manually clean the filter when the backwash cycles would not regenerate the filter to its original operating pressures. If the water source contains high amount of suspended matter, especially filamentous and mucous matter, it was observed that backwashing is not efficient and manual cleaning was needed [30].

Table 2: Filter backwash cycles and cleanings [30]

Cleaning type	Automatic				Manual cleanings		Total	
	Efficient		Inefficient					
Inlet pressure (kPa)	300	500	300	500	300	500	300	500
Screen filter	85	111	766	52	58	2	913	173
Disc filter	153	128	1	37	28	1	184	173

In a study conducted by the Agricultural Water Management, it was observed that the backwash efficiency of disc filters increase at higher operating pressures and therefore the amount of manual cleanings required decrease significantly [31]. Also, the filter operation time for disc filters was longer after manual cleaning than after automatic backwashing [29].

2.5 Ultraviolet Disinfection

Ultraviolet light is electromagnetic radiation having a wavelength of 100-400nm. Light in the UV spectrum is further divided into four segments: vacuum UV, short-wave UV (UV-C), middle-wave UV (UV-B) and long-wave UV (UV-A). The location of UV light and its subdivisions within the electromagnetic spectrum is illustrated in the figure below [31].

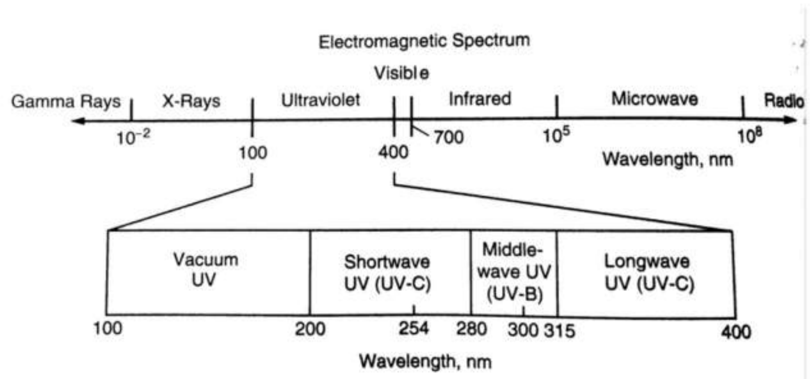


Figure 12: Ultraviolet light region within the electromagnetic spectrum [11]

The more energy associated with each photon in electromagnetic radiation, the more dangerous is it for living organisms. The relation between the energy associated with each photon and the wavelength of radiation is shown by the equation:

$$E = \frac{hc}{\lambda}$$

Where:

E = energy in each photon, J

h = planck's constant, 6.6×10^{-34} J.s

c = speed of light, m/s

λ = wavelength of radiation, m

2.5.1 Germicidal Range of Ultraviolet Light

The portion of the UV spectrum that is most effective for disinfection is called germicidal range [11]. On the lower end of the UV spectrum, the UV radiation is absorbed by water which limits the germicidal range. UV deactivates the microorganisms in water by transforming their DNA. However, this process only occurs when the DNA is able absorb the UV. The absorption process of UV by DNA does not occur at wavelengths above 300nm. Therefore the germicidal range of UV is between 200nm – 300nm.

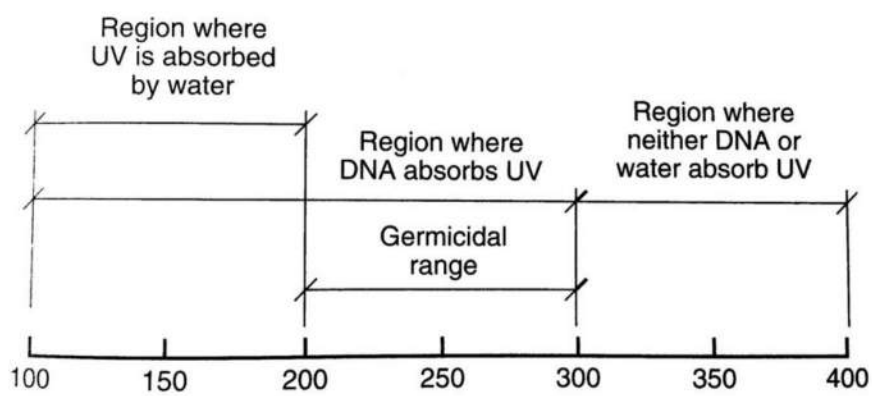


Figure 13: Germicidal range of ultraviolet light [11]

2.5.2 Ultraviolet Light Dose

The effectiveness of UV disinfection is directly related to the UV dose to which the pathogens in water are exposed:

$$D = I_{\mathrm{avg}} t$$

Where:

D = UV dose, mJ/cm^2 ($mW.s/cm^2$)
I_{avg} = average UV intensity, mW/cm^2
t = exposure time, s

The UV dose can be varied by either altering the UV intensity or the exposure time. The quality of water being treated has significant impacts on UV disinfection systems. The design controls the flow rate obtain a UV dosage of $41mJ/cm^2$ which exceeds the standards set by the EPA [11].

2.5.3 The Effect of Suspended Solids on UV disinfection

Suspended solids can interfere with the transmission of UV light and therefore the quality of water passed through is important when UV disinfection is utilized as a filtration mechanism [33]. Two mechanisms of particular importance are encasement and cases of shading as illustrated by figure 13.

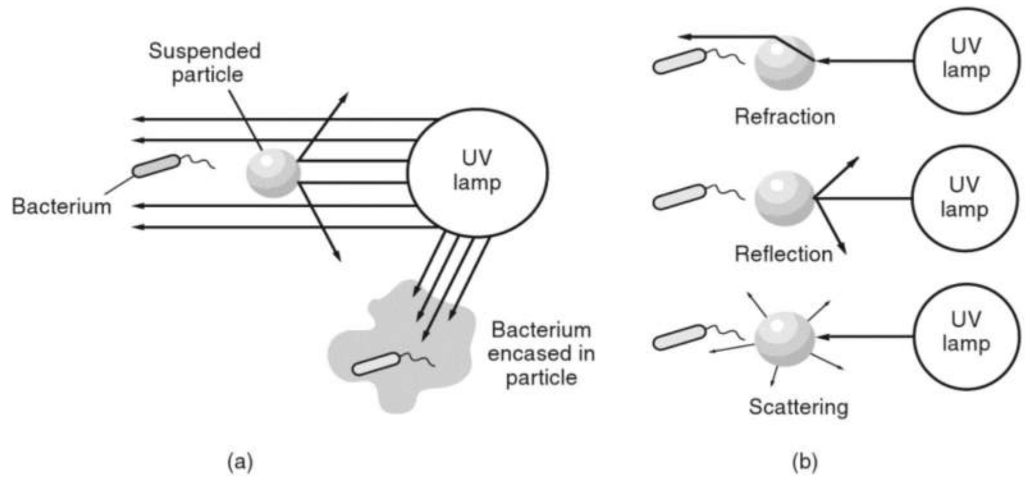


Figure 14: Illustration of (a) encasement and (b) cases of shading

These effects are mainly experienced when the UV filter is used on highly turbid water sources. With the use of filtration mechanisms before UV disinfection, the effects of encasement and shading can be reduced or completely eliminated [34].

Chapter 3

Methodology

This chapter presents the initial design challenges that was experienced during ERAU Project Haiti 2010 and 2011. These challenges forced the team to reevaluate the customer requirements and engineering specifications of the system.

3.1 ERAU Project Haiti

The earthquake that struck Haiti in 2010 destroyed what was left of an already poor infrastructure and took the lives of over 200,000 people [35]. This catastrophic event motivated ERAU students and stuff to establish ERAU Project Haiti, a student led movement to improve the lives of many Haitians. Since 2010, ERAU students and faculty have visited Haiti each year and have installed solar powered water purification systems in various Haitian communities.

3.2 Project Haiti Successes and failures

Soon after the earthquake in 2010, ERAU students built a water purifier to support the American relief workers to facilitate the disaster response [36]. This project was a collaboration between ERAU and Nehemiah Vision Ministries, a Non-Profit Organization based in Haiti. With funds raised from the local student chapter of American Society of Mechanical Engineers (ASME), ERAU students designed a water purifier to provide clean drinking water to 150 volunteers. The system was a temporary solution that provided clean water at 1 gallon per minute (GPM) and was powered using a solar panel. The success of Project Haiti 2010 attained the interest of many other organizations in Haiti, who were looking clean water solutions for their community.

In 2011, ERAU students were approached by the Anne Clemande Julien Foundation. The project included the design and installation of a solar powered water purification system at a school in Chambellen, Haiti that served 600 students [37]. The goal of the project was to provide a permanent clean water solution for daily operations of the school. The project Haiti 2011 purifier was a scaled up version of the one designed for 2010. The system operated at 4GPM was able to provide 1200 gallons of water a day and was designed to meet the standards set for drinking water quality, however it required frequent cartridge replacement. Since the orphanage was 12 hours away from the country's capital city, Port-au-Prince, it was difficult for the school to gain access to cartridge filters. The cost of maintaining the purifier due to filter replacements was an additional burden for the school. Eventually, ERAU stopped receiving updates on the purifier and so communications between ERAU and the Anne Clemande Julien Foundation stopped as well.

At this point, the team was forced to reevaluate the design to be more self-sustainable and suitable for developing nations. The design model introduced in this thesis includes a combination of the practices implemented in design and installation process of project Haiti 2012, 2013 and 2014 systems which are currently in operation without any setbacks or technological failures.

3.3 Customer Requirements list

Understand the customer and their needs is an essential part of any design process. After working with multiple NGOs and installing five purification systems in Haiti, the team has defined the most common and essential customer requirements that needs to be met to provide a sustainable and effective water purification solution for a developing nation. The purification unit shall:

3.3.1 Provide safe drinking water to a Community. There is a obvious shortage of clean water in developing nations [38]. Majority of communities rely on a single source of water for the whole community and water lines to houses is not very common [39]. For this reason, the system must provide a minimum of 10,000 gallons of clean water per day, enough to sustain the water needs of a small community. In addition to volume, the system must meet the drinking water standards set by the EPA for microbial contaminants.

3.3.2 Consist of a standardized design that is scalable for different communities. Depending on the size of the community and accessibility to a water source, the amount of water required at each location is different. The technology needs to be scalable such that system is able to provide the required amount of water for the community without major changes or modifications.

3.3.3 Consist of simple operational tasks. The daily operations needs to be simple and should not require a technical operator. System operation instructions need to be simple to understand and apparent to local operators in the commissioned area.

3.3.4 Operate with low costs. Even if water is an absolute necessity, due to high maintenance costs, a system that requires frequent cartridge replacement is not appealing to communities in developing nations [37]. This was very evident from project Haiti

2011. Keeping maintenance costs to a minimal is absolutely essential for a successful project.

3.3.5 Operate off-grid. Lack of a constant power supply is another common issue in developing nations [40]. The system needs its own reliable power supply that allows it to be operated where ever a water source is available.

3.3.6 Serve a community for a long period of time. When an NGO approaches ERAU to provide a clean water solution to a certain community, it is often expected that the system is reliable and will be permanent solution. Therefore, the systems should operate for a 4 -7 years without requiring any major components to be replaced.

Chapter 4

Water Purification System Design

This chapter presents the purifier design that was implemented in three Haitian locations. Using suitable technology a standardized purifier design that is scalable to meet the needs of different sized communities was achieved.

4.1 Project Haiti Purifier Design

Figure 15 illustrates the standardized design, a purification system capable of producing 10,000 gallons of water per day relying solely on solar power. The system specifications of the purifier is listed on Table 2.

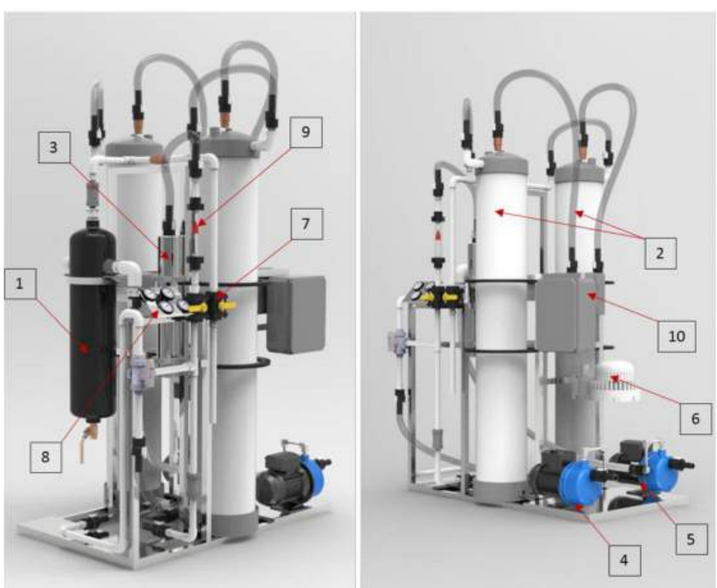
Figure 15: CAD of project Haiti 2013 Purifier Design (Standardized Design)

Table 3: Standardized System Specifications

Standardized Design System Specifications	
Flow Rate	**10 GPM**
Gallons of water filtered per day	**10000 Gallons**
Primary Filtration Mechanisms	**UF Membrane Filtration + UV Disinfection**
Operation Mode	**Manual**
Annual Maintenance Cost	**$135**
Primary Power Source	**Solar**
Estimated Design Life	**4-7 years**

4.2 Standardized Design with Scalable Technology

Figure 16 illustrates the major components of the purifier designed for Project Haiti 2012. The system is capable of producing over 20,000 gallons of water per day and uses the same major components as the standardized design except for an additional UF Membrane filter.



1	Helix Disc Filter
2	Ultrafiltration Membrane Filter
3	Ultraviolet Disinfection Filter
4	Inline Pump
5	Backwash Pump
6	Air Blower
7	Control Valves
8	Pressure Gauges
9	Flow Meter
10	Control Box

Figure 16: CAD of Project Haiti 2012 Dual Membrane Purifier Design

By using Ultrafiltration membranes as the primary filtration source, the purifier can easily be scaled up or scaled down without requiring major modifications. In other words, it allowed for a standardized design. For example, if a customer requires a community scale purifier to produce over 20,000 gallons of water, another Ultrafiltration membrane filter can be added to the standard design which will increase the filtration capacity to 30,000 gallons per day.

4.3 Stages of Purification

The system utilizes three stages of filtration and this is illustrated in figure 18. The microbiologically contaminated source water is first passed through a Helix Disc Filter, the first stage of filtration. The Disc Filter used in the design eliminates contaminants larger than 50 micron in size. The relevant sizes of common microbiological contaminants are illustrated in figure 17.

Pathogen	Approx. Size (microns, µm)	Specific Examples
Bacteria	0.2 - 2	E-coli, cholera, typhoid (salmonella), shigella, fecal coliform, STREP, STAFF (food poisoning)
Viruses	0.02	Polio, Hepatitis-A, influenza
Spores	6 – 8	Dormant phase of protozoa, chlorine resistant
Protozoa	6 - 10	Giardia, Cryptosporidium
Algae	0.5 - 60	Green – ok Blue/green algal blooms (cyanobacteria) toxic – boiling does not disinfect!
Helminthes	>20, eggs	Parasites, tapeworm, roundworm, flukes, trichinosis; adults 5cm – 1m!

Figure 17: Common Microbiological contaminants and their relevant size

The primary purpose of the disc filter is to remove large sediments from the water source. As the water passes through the discs, the grooves on the surface of the discs restrict sediments larger than 50 micron from passing through [41]. The plastic discs require to be manually cleaned once the TMP across the filter increases. A high velocity centrifugal action inside the filter housing forces the sediments to spin away from the discs and into the base of the filter [40]. A flush port at the base of the filter housing allows the accumulated sediments to be flushed out which minimizes the maintenance required on the discs.

The second stage of filtration uses UF membrane technology, which is the primary filtration mechanism. The UF membrane filter is able to remove contaminants as small as 0.1 micron. As illustrated by figure 17, at this level, the filter is able to effectively remove majority of harmful contaminants from the water source. Certain harmful viruses, which are smaller than 0.1 micron such as polio, hepatitis-A and influenza is able to pass through the porous surface of the membrane. Therefore, a third stage of filtration is required to effectively remove these pathogens. With proper maintenance, the membrane filter has a design life of 4-7 years [42].

Third and final stage of filtration is an Ultraviolet disinfection filter which deactivates the DNA of the remaining viruses. The UV bulb, which costs $75 is able to provide 9000 hours (365 days) of constant UV output before requiring to be replaced [43]. Since Ultrafiltration membrane filters are field serviceable due to their backwash capabilities, the UV bulb is the only filtration component that requires replacement. Figure 18 illustrates hydraulic flow and the three different stages of filtration.

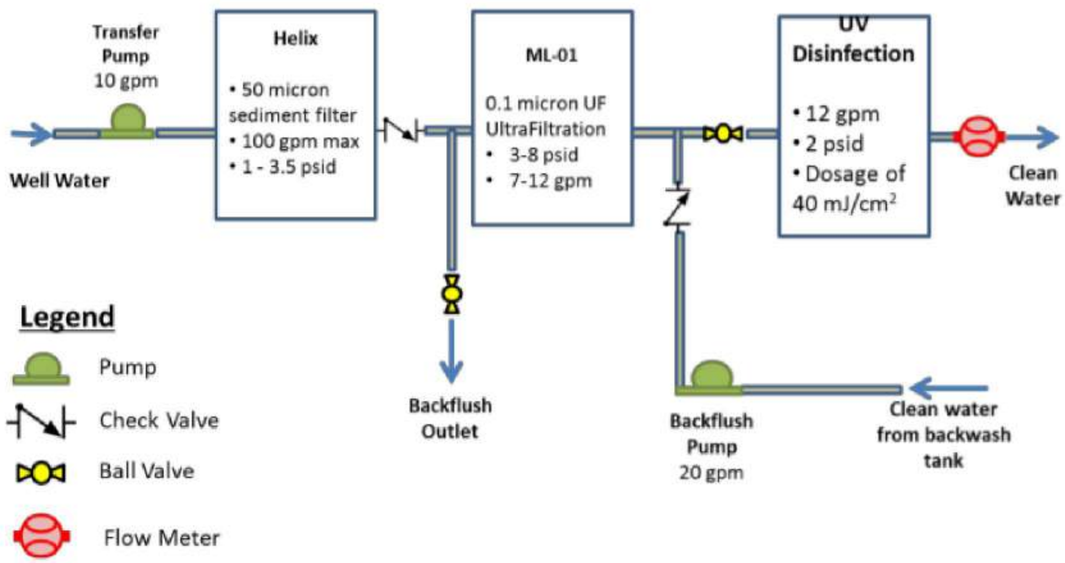


Figure 18: Hydraulic Flow Schematic for a single membrane design

4.4 System Water Purification Standards

Table 4 illustrates the reduction level achieved by the purifier in comparison to filtration standards set by the EPA for microbiological filtration systems. Filtration mechanisms used in the design exceeds the EPA standards. The 0.1 micron UF filter effectively removes bacteria and protozoa. In addition, UF filtration is able to achieve turbidity levels below the required 1 NTU standard [44]. At a flow rate of 10gpm, the UV filter provides a dosage of 41mj/cm^2 [42], which exceeds the EPA standards.

Table 4: Filtration standards achieved by purifier in comparison to EPA standards

Microbial Contaminant	Required Reduction Level	System Reduction Level	Filtration Technology
Bacteria	99.9999% (log 6)	>log 7	0.1μm UF Membrane
Virus	99.99% (log 4)	>log 4	UV Disinfection (41mj/cm^2)
Protozoa	99.90% (log 3)	>log 7	0.1μm UF Membrane
Turbidity	≤1NTU	≤0.01NTU	0.1μm UF Membrane

4.4 Mechanical & Hydraulic Design

This section discusses the design methods utilized for the Mechanical and Hydraulic portion of the purifier. The overall layout of the hydraulic design, pump selection processes and methods implemented for a simple system operation are presented.

4.4.1 Site Layout

Figure 19 illustrates a typical site layout that is planned and put into place with the collaboration of the local partner. Using a solar pump, the ground water is stored into a tank. The transfer pump of the purifier pumps the non-potable water through the filtration stages and into a potable water tank. The potable water tank is placed on a raced platform so that the purified water can be gravity fed into the bucket fill rail. This eliminates the need for an additional pump.

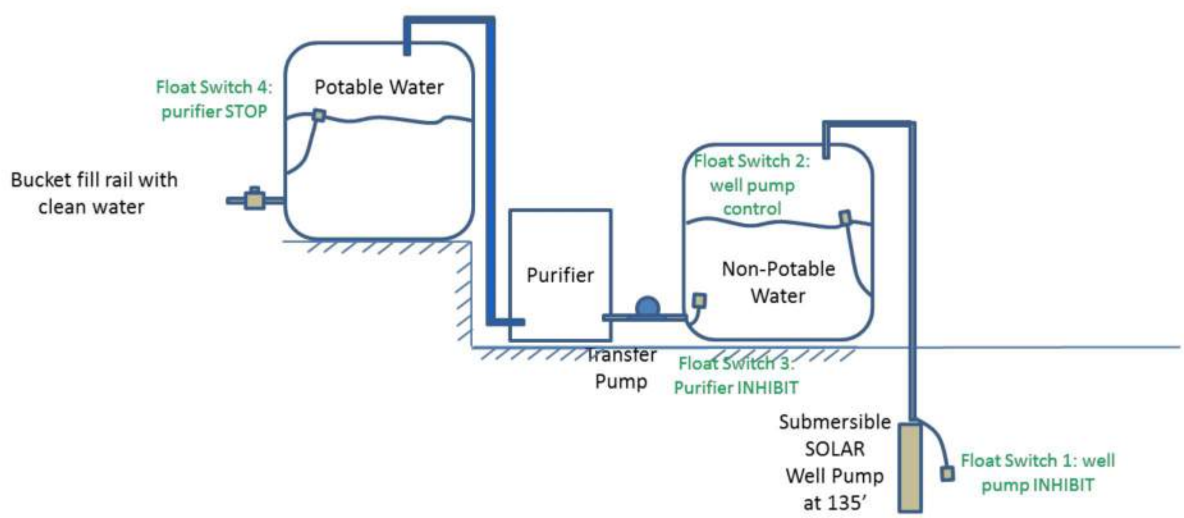


Figure 19: Project Haiti 2013 Site Layout

4.4.2 Modes of Operation

The system operates in two different modes, Filtration mode and Backwash mode. As mentioned before, during filtration mode, the water is passed through the three stages of filtration and the clean water is pumped through into a tank placed on a raised platform. Backwash mode is used for cleaning the membrane filter once clogged. A mix of clean water, chlorine and air is passed through the membrane filter in reverse direction using the backwash pump and the air blower. The system can be switched between the two modes through a simple valve mechanism. The pictorial guide handed to the local operators to switch between the two modes in illustrated in figure 23. The path through which water passes during these two different modes of operation needs to be considered to select the appropriate pumps. The overall pressure losses due to various components and the length of plumbing used at the site determines the operating pressures of the system

4.4.3 System Operating Pressure

The total head loss (h_{LT}) is the energy dissipation of a fluid due to frictional losses as the water passes through various components in a system and is expressed by the equation below.

$$h_{LT} = h_L + h_{LM}$$

Head loss in a system is generally divided into two main categories, major losses(h_L), which are associated with loss of energy due to the wall friction of pipes, and minor losses(h_{LM}), associate with sudden changes in flow characteristics due to pipe fittings such as valves, tees and elbows. Major and minor losses in a system are calculated using the Darcy's equation:

$$h_L = f\frac{L}{D}\frac{V^2}{2g}$$

$$h_{LM} = K\frac{V^2}{2g}$$

Where:

F = Darcy friction factor
L = Length of pipe
V = Average velocity of fluid flow
D = Hydraulic diameter of pipe
g = Acceleration due to gravity
K = Loss coefficient factor

For a piping system with multiple minor losses, the equation the total head loss h_{LT} can be written in the following form:

$$h_{LT} = \left(K_p + K_1 + \cdots + K_n\right)\frac{V^2}{2g}$$
$$K_p = \sum f\frac{L}{D}$$
$$K_{1\cdots n} = \sum f_n\frac{L}{D}$$

Where:
K_p = coefficient loss of factor for pipes
$K_{1\cdots n}$ = coefficient loss factor of fittings
The total head loss of a system expressed in the form of pressure loss, Δp as the height of a column of fluid:

$$\Delta p = \rho \cdot g \cdot h_{LT}$$

Which can also be written in the form:

$$\Delta p = \left(K_p + K_1 + \cdots + K_n\right)\frac{\rho V^2}{2}$$

Where:
ρ = Density of fluid

The total pressure losses due to system fittings, pipe lengths and various filtration components for the project Haiti 2013 single membrane system at the required flow rate of 10gpm are illustrated in Table 1. The minimum operating pressure of the system was calculated to be 23.75 psi and a 31.26psi the maximum operating pressure. A pump that would effectively produce roughly 10gpm at a pressure of 23.75psi is then selected as the inline pump of the purifier.

Table 5: Total Pressure losses

Pressure Loss due to system fittings at 10gpm flow rate		
Connection Fittings	No. Of Components	Pressure Loss(psi)
1" PVC Elbow	10	0.8
1" PVC T-connector	3	0.68
1" Check valve	3	9
1" Ball Vale	3	0.4
1" Camlock Fitting	8	0.92
Total		**11.8**
Pressure Loss due to system plumbing at 10gpm flow rate		
Piping Type	Equivalent Length(ft.)	Pressure Loss(psi)
1" PVC	30	0.64
1" Flex Hose	10	0.25
1.5" PVC	20	0.07
Head loss due to elevation	10	4
Total		**4.96**
Pressure Loss due to system filtration components		
Filter Type	Minimum Pressure	Maximum Pressure
Helix Disc Filter	1	3.5
UF Filter	3	8
UV Filter	3	3
Total	**7**	**14.5**
Minimum Operating Pressure	**23.75 psi**	
Maximum Operating Pressure	**31.26 psi**	

The calculation process is always an assumption of what the pressure losses of the system would be. It is difficult to calculate the exact operating pressure of the system due to changes that occur during installation. Due to lack of availability of components and certain inconveniences that are experienced in developing nations, the installed hydraulic system has never been the exact version designed beforehand. The pumps for the system are selected using the following process:

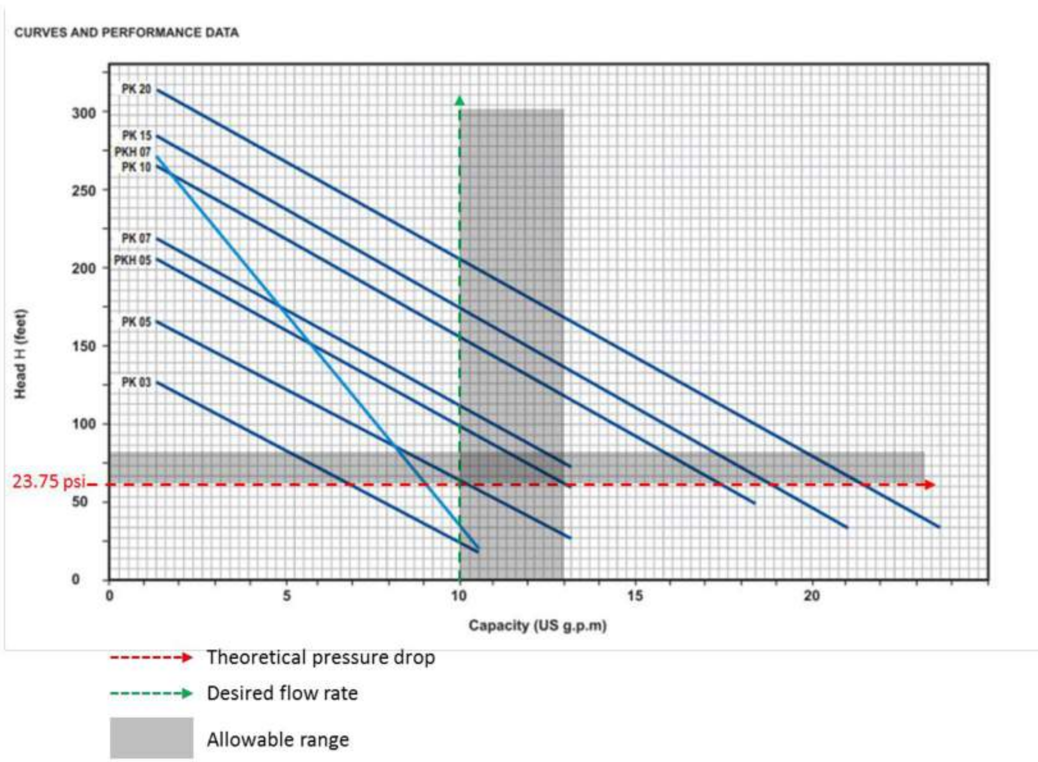


Figure 20: inline pump selection criteria

$$Allowable\ Pressure\ range = Theoretical\ \Delta P + 5psi$$

$$Allowable\ Flow\ rate\ range = Desired\ flow\ rate + 3gpm$$

When selecting the pumps, it is always assumed that the system would have a higher operating pressure than calculated. It is preferable to have a pump that provides water at a higher flow rate than the desired flow rate. A ball valve is inserted right at the outlet of the inline pump to restrict flow and to increase the system's operating pressure if the flow rate exceeds the capacity that filters can handle

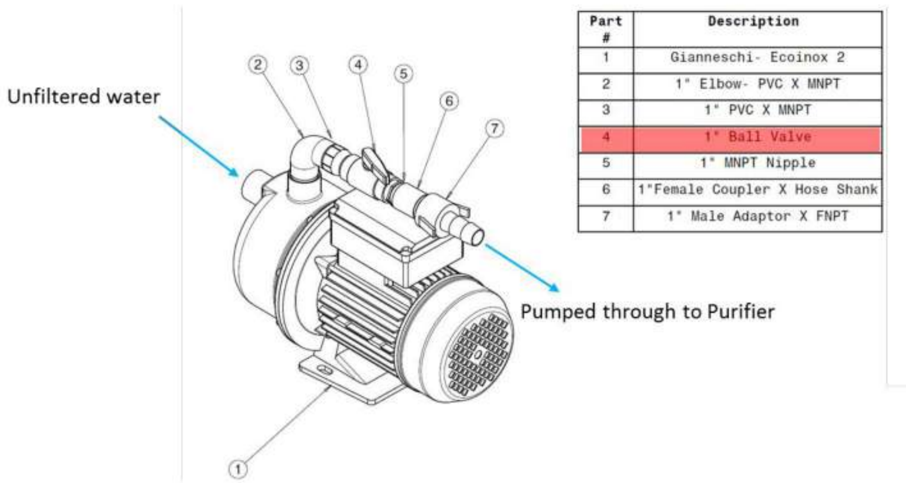


Figure 21: Ball valve at outlet of inline pump to increase system operating pressure

With past project experiences, it is now possible to estimate the overall pressure losses for single and dual membrane designs, assuming the overall site layout remains similar to the one illustrated in figure 19. The required pump specifications for different systems are illustrated in Table 2:

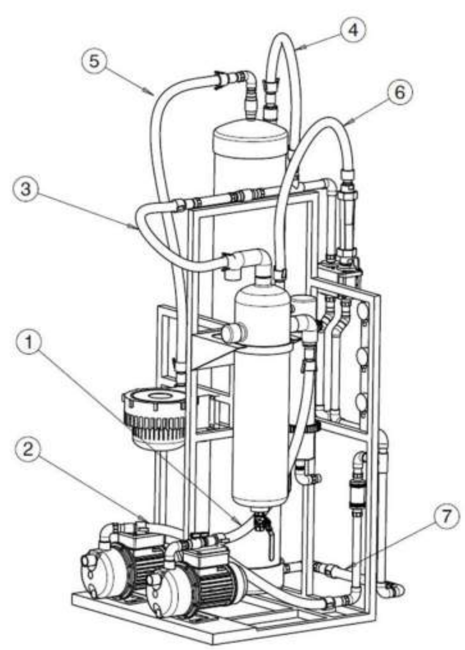
Table 6: inline and backwash pump characteristics

Characteristics	Inline Pump	Backwash Pump
Flow range(GPM)	10 to 15	15 to 20
Pressure range(PSI)	20 to 25	10 to 15
Motor Type	TEFC	TEFC
HP Standard	≤ 1HP	≤ 1HP
Phase	1	1
Self-Priming	yes	yes

4.4 System Maintenance

A technical user manual consisting of proper cleaning intervals, CAD, electric and hydraulics schematics, data sheets and troubleshooting guides are handed to the local operators in case the system malfunctions. A technical personnel that is available locally has sufficient information to solve any system errors with the aid of the user manual. A copy of the user manual can be found in Appendix D. During installation, a full day is allocated to train the locals and to express the importance of proper maintenance practices.

The system uses camlock fittings and flex hoses at the inlet and outlet of each filtration component. This facilitates the maintenance of system since each filtration component can easily be removed in case of repair, filter replacement, or general maintenance.



Part #	Description
1	Inline Flow-1"
2	Backflush Flow-1"
3	Helix Filter Outlet-1"
4	UF Water Inlet-1"
5	UF Air Inlet-1"
6	UV Water Inlet -1"
7	UF Water Outler-1"

Figure 22: Use of camlock fittings to facilitate component replacement

4.4.4.1 Helix Filter Manual Cleaning

The filter discs of the Helix disc filters require to be rinsed off once a week. The frequency at which the discs needs to be cleaned depends solely on the quality of the water that is being filtered through. In addition to being manually cleaned weekly, the local operators are also told to be aware of the maximum operating TMP of the filter of 3.5 psi. If the TMP reaches 3.5 psi, the operators are asked to manually clean the Helix filter immediately.

4.4.4.2 Backwash Cleaning Characteristics

During backwash mode, purified water mixed a chlorine dosage of 6 ounces for 30 gallons is passed through the UF membrane in reverse direction. Simultaneously, air is passed through with the mixture of water and chlorine at high velocity. The relay timers provide air only for 30 seconds, then a combination of air and water or the final 30 seconds of the backwash cycle. As explained in the literature review, the use of air and chlorine increases the efficiency of backwash cycles. Air and chlorine helps to effectively remove the cake layer that forms on the membrane surface after a period filtration [43]. The overall effectiveness of backwashing is directly related to the contamination of source water. To ensure that the membrane filter lasts up to its proper design life of 4-7 years, the operators are asked to backwash the system every hour.

4.4.4.3 Pictorial Guides

The system is designed to be operated without the need for a technical operator. The local operators can refer to the designed pictorial guide for daily operations of the purifier.

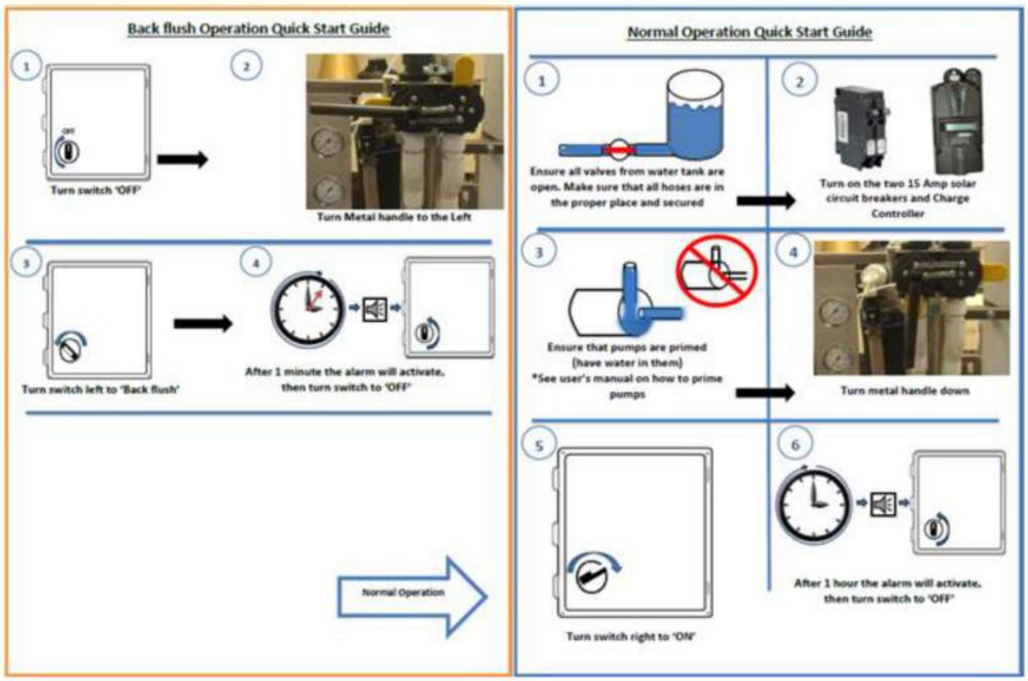


Figure 23: Pictorial User Guide

4.5 Electrical and Power System design

This section discusses the design steps implemented for the included power system of the purifier. The purifier loads, the sizing of the battery bank and the design of the solar array are explained in detail.

4.5.1 Use of Electromechanical Components

The electrical system of the purifier avoids the use of sensitive electronics and automation to avoid complexity. The electrical system is designed with no onboard computers and with low chance for failure in the field. Electromechanical timer relays are utilized to set the time for filtration run time and backwash runtime. After filtering water for one hour, the timer used for filtration mode shuts off and sets off an alarm to indicate to the operator to switch the system to backwash mode. Once the system operates in backwash mode for 1 minute, the system shuts off and sets off the alarm once more to alert the operator to switch the system back to filtration mode.

4.5.2 Power Consumption

The system is powered using solar panels. The design of the power system begins by determining the total energy that is consumed by the various loads in the system. The components that require power and their total solar energy requirement per day is listed in the table below.

Table 7: Purifier Loads

Component	Power Requirement(W)	Time(hours)	Energy (Wh)
Inline Pump	373	8	2984
Backwash Pump	373	0.13	48.49
Air Blower	373	0.13	48.49
UV Filter	43	48	2064
Total			**5144.98**

The total energy consumption allows to determine the required battery bank size. The UV bulbs is required to be switched on at all times to avoid deterioration of its proper design life. For this reason, the margin for the UV bulb is set for 2 days without out sun.

4.5.3 Battery Bank

The total energy storage of the system is generally twice the energy consumption of the system since battery bank state of charge of deep cycle batteries should not reduce below 50%. So the required number of batteries for the total loads should be doubled:

$$Number\ of\ Batteries\ required = \frac{Total\ Energy}{Battery\ Energy} \times 2$$

For Project Haiti 2013, locally sourced Rolls-Surrette S530 deep cycle batteries with a voltage of 6V and a capacity of 2400Wh was used. So the number of batteries required for the system is:

$$Number\ of\ Batteries\ required = \frac{5144.98\ Wh}{2400Wh} \times 2 = 4\ Batteries$$

Connecting these batteries in series provides 24V bank voltage. The battery bank voltage determines the selection of the charge controller which transfers the power obtained from the sun into the battery bank. The charge controller regulates the power transferred into the battery bank so that unsafe conditions such as over heating or over charging is avoided.

The purifier loads draw power from the battery bank. Since the battery bank provides DC power, a power inverter is used to convert from DC to AC power. The components that require AC power for the 2013 purifier is illustrated in figure 24. The inverter is sized using the sum of all power loads and the component that requires the highest startup current. The backwash pump has the highest start up current of 41 amps, which equates to over 4000W of a power draw from the inverter during start up. The rest of the loads draw roughly 1000W of power during start up. A 5000W inverter with surge capacity of 10,000W was selected for the system.

4.5.4 Solar Array

The solar array is designed assuming just 5 hours of peak sunlight is available at any particular location. Dividing the total energy required for the purifier by five hours of sunlight determines the theoretical solar power required:

$$P_s = \frac{Total\ Energy}{Peak\ Sun\ Hours} = \frac{5144.98Wh}{5\ hours} = 1028.99W$$

An 80% de-rating factor needs to be taken into account since solar panels do not operate at their nameplate rating due to heating and line losses. With 80% de-rating factor, the required solar power amounts to 1234.7W. Six 250W solar panels were purchased for a total of 1500W to power the purifier electronic components. Figure 24 summarizes the power system of the purification system.

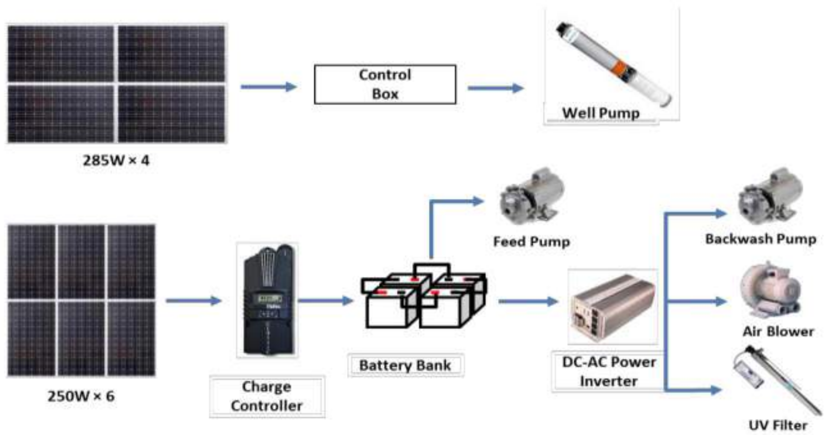


Figure 24: Power System Schematic for 2013 Design

Chapter 5

Testing & Results

This chapter demonstrates the different testing that was performed on the system to validate its functionality. Filtration integrity is tested to confirm that the purifier is able to eliminate harmful microbiological contaminants. Backwash capabilities are also tested to confirm the clean-in-place design of the system.

5.1 Purifier Testing

The systems are tested at Miller-Leaman, a local water purification company. ERAU utilizes Miller-Leaman test facilities to confirm that systems operating at proper standards before shipping them off to the community. Figure 25 illustrates the test facility that was made available to ERAU by Miller-Leaman.

Figure 25: System being tested at Miller Leaman wet table

5.1.1 Membrane Integrity Testing

Clay test dusts rated at 1-100 micron is used to test the performance of the membrane filter. Since the UF membrane is rated at 0.1 micron, all the clay dust particles are retained by the filter during filtration mode. Clay dust is added into a water sample to increase the cloudiness up to 10 NTU. The NTU of the after passing through the membrane is also measured. The NTU of the filtered water was measured to be 0.01 NTU indicating that test was successfully retained by the UF membrane.

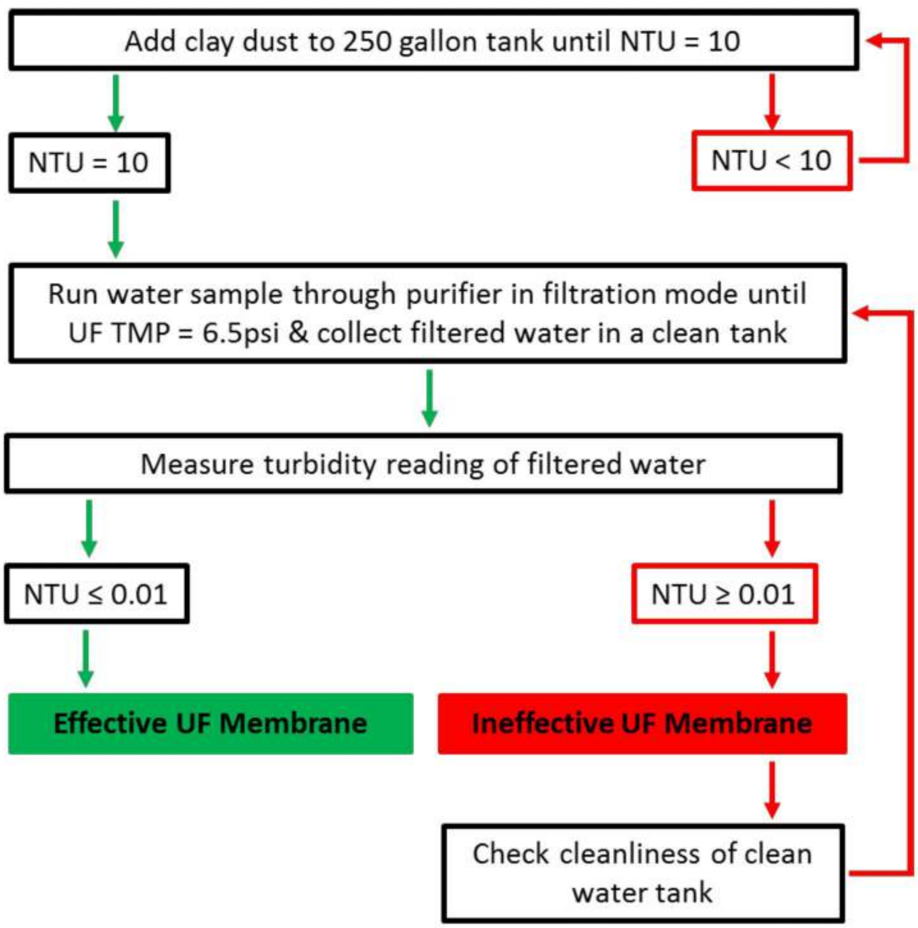


Figure 26: membrane integrity testing flow chart

5.1.2 Backwash Effectiveness

After performing Clay dust tests, the system is backwashed to remove the clay dust that was retained by the membrane filter. It is made sure that the backwash pump and air blower starts at the correct times and runs for the duration set by the timer relays. The NTU of the backwash effluent is also recorded. If the system is backwashed effectively, the NTU of the backwash effluent should read roughly 10NTU for 250 gallons of water, the original cloudiness of the water sample that was filtered through the system. The backwash effectiveness testing flow chart is illustrated in figure 27.

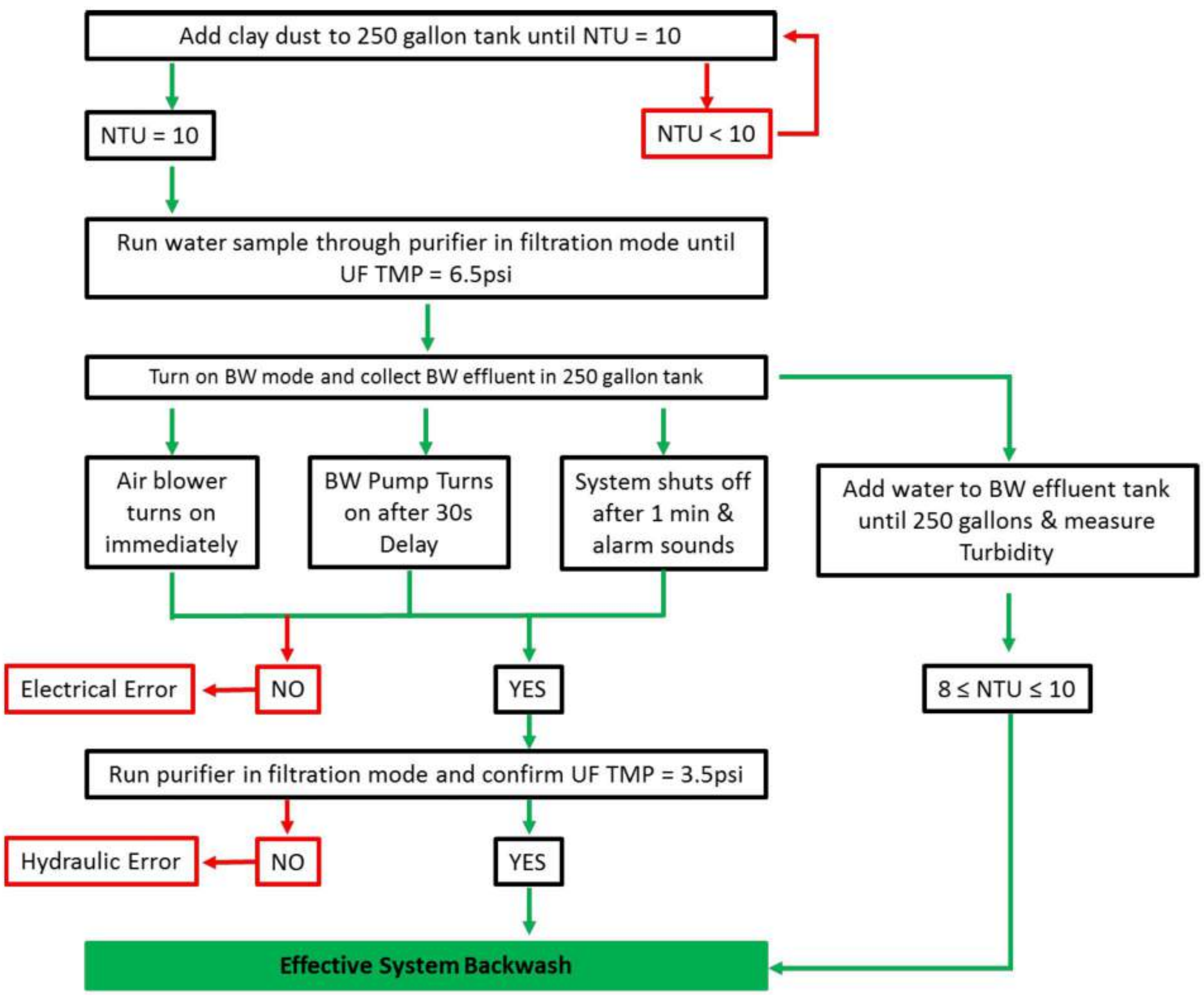


Figure 27: Backwash effectiveness testing flow chart

5.1.3 Transmembrane Pressure Tests

The system monitors the transmembrane pressures of the Helix filter and the UF filter and allows an operator to know if the system is performing at the correct pressures. The pressure gauge mount of the 2013 purifier is shown in figure 29.

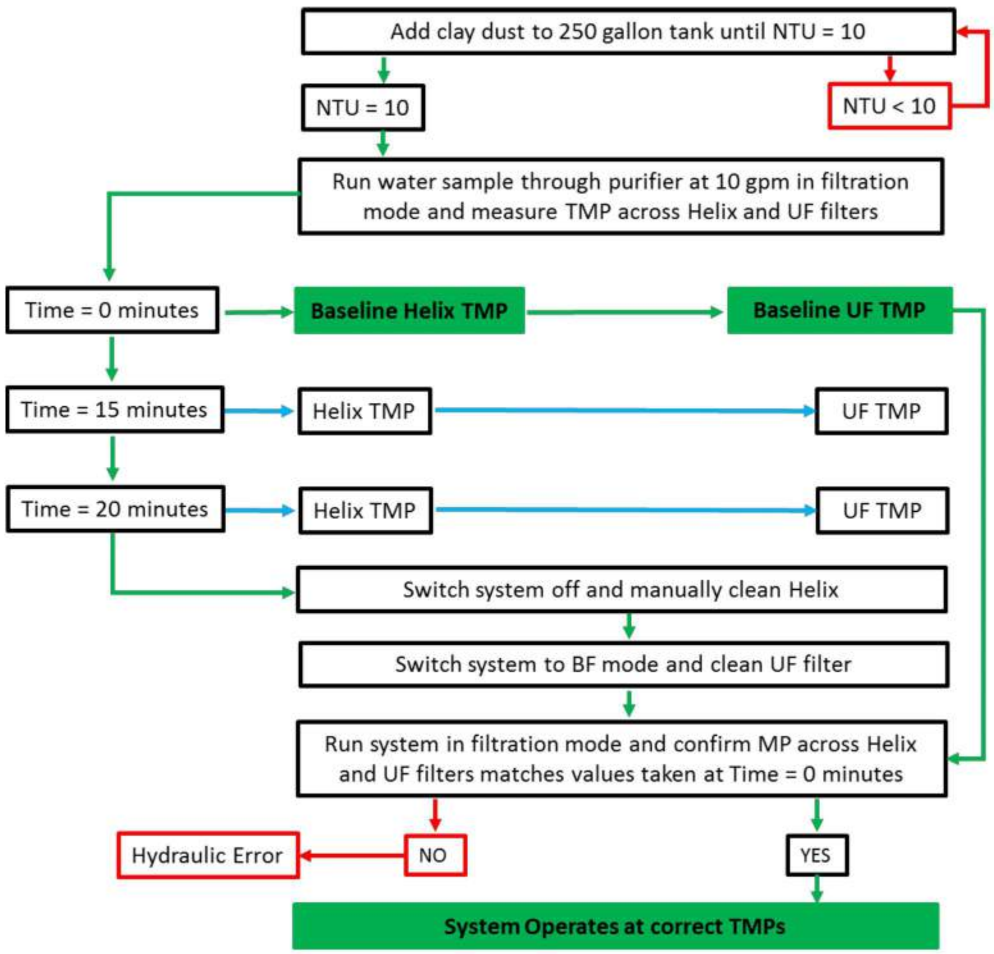


Figure 28: transmembrane pressure testing flow chart

The baseline pressures of the system are recorded when the filters are clean. Then using clay dust, the filters are purposely clogged and then backwashed to check if the transmembrane pressure reaches its original value. The Helix disc filter is manually cleaned. The pressure across the UV filter is not monitored as it will always remain the same.

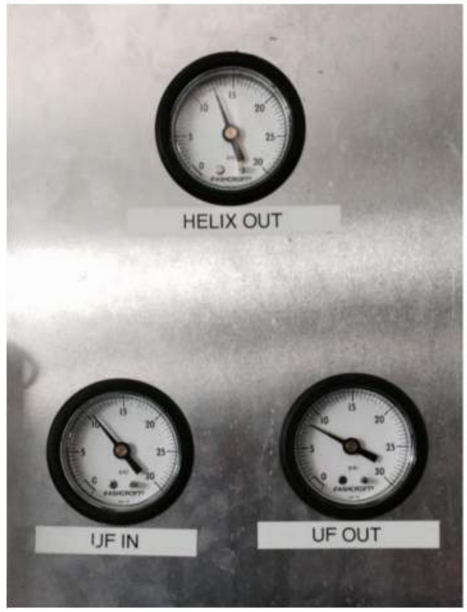


Figure 29: Pressure gauge mount

5.1.4 Effluent Water Quality

Bacteria tests are performed on a well water sample and a purified water sample to ensure that the filtration system eliminates contaminants and provides safe drinking water. Figure 30 compares two water samples after 48 hours.

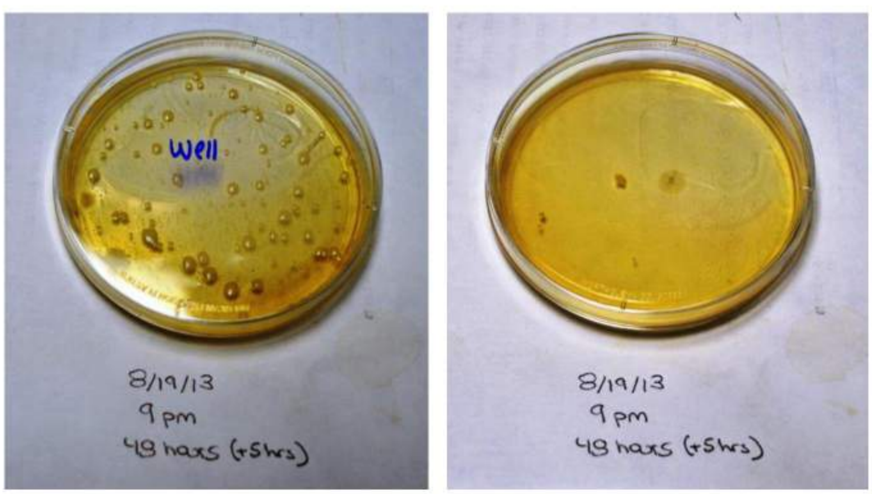


Figure 30: Bacteria tests of Well Water vs Purified water

More than 5 colonies of bacteria are considered as an abnormal amount and unsafe for consumption. The well water clearly has many colonies of bacteria and the difference in water quality after being purified is very clear.

5.2 Current Status of Fielded Systems

Each year, the team visits the pervious sites to monitor the performance of the systems. The team ensures that the installed system is operating at allowable pressures and backwashes effectively. Since implementing the system in three different locations, to the writing date of this thesis there has not been any major malfunctions. Certain issues that were reported to the team by the local installation partners of different communities are summarized in this section.

5.2.1 Project Haiti 2012 System – Onaville Relief Camp, Onvaville Haiti

The purifier design was first implemented during Project Haiti 2012. ERAU installed a dual membrane purifier at the largest displacement camp in Haiti in August 2012. The system is capable of producing 20,000 gallons of water per day operating 15gpm. The system is currently in operation and provides water to locals in the area on a daily basis.

5.2.1.1 Inverter Malfunction

The battery bank of the 2012 system consists of a 48V bank voltage. An error was made by one of the local operators when connecting the batteries which altered the bank voltage and consequently destroyed the inverter. Inverter of the system was replaced during the Project Haiti 2013 installation trip.

Figure 31: Project Haiti 2012 Purifier

5.2.2 Project Haiti 2013 System – Ryan Epps Home for Children (REHC), Michaud Haiti

In August 2013, ERAU installed a single membrane purification system at REHC. The system provides clean drinking water to meet the needs of 200 students and stuff at the Orphanage.

5.2.2.1 Addition of a Carbon Filter

ERAU introduced the concept of a micro business where extra water from the purification system can be sold to the surrounding community to generate income which can be used for system maintenance and daily operation. The sales from water business was low due to other water selling businesses in the local area utilizing carbon filters which improve the taste of water. Even though the water sold by these local businesses were not of drinking quality, locals were used to the taste of carbon and was not keen on consuming water sold by REHC. A carbon filter was installed during the 2014 Haiti trip per request of REHC in an effort to increase sales from the microbusiness.

The water quality of local sellers and is shown in figure 32. The team uses Hach pathoscreen test kits, a powder that is added into water samples to promote bacteria growth. If the water color changes from its original tone (0 hours), it means that bacteria is present in water. It is clear from the image that J&J is selling highly contaminated water to the public.

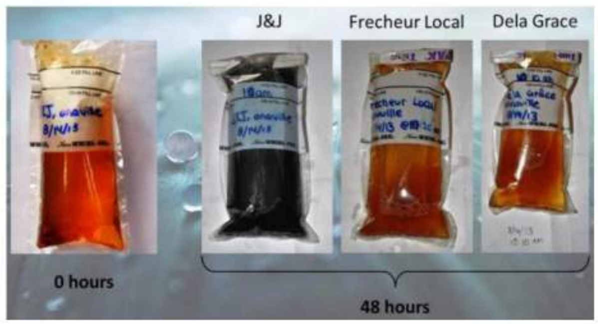


Figure 32: water quality of local water vendors

5.2.3 Project Haiti 2014 System – Dayspring Mission Orphanage (DMO),

In August 2014, ERAU installed a single a membrane purification system at DMO to provide safe drinking water to children and stuff. The system was successfully commissioned and functions as designed.

5.2.3.1 Standardized Design with a Incorporated Carbon Filter

After project Haiti 2013, the team focused more on the microbusiness aspect of the project. With the lessons learnt from REHC, the team decided to incorporate the carbon filter into the standardized design. DMO is currently selling water in three different locations in Port-au-Prince, Haiti. CAD of 2014 system is illustrated in Figure 33.

Figure 33: Standardized design with the addition of a carbon filter

Chapter 6

Discussion, Conclusions, and Recommendations

6.1 Discussions

Table 5 illustrates how each system specification of the standard single membrane design meets the customer requirements. The system is able to provide 10,000 gallons of water to a community operating at 10 GPM. Since the system uses UF membrane as its main filtration mechanism, the system can be scaled up by introducing an additional membrane unit. The components selected in the system are durable and will keep the system in operation for many years. With proper servicing the main filtration component of the system, has a design life of 4-7 years. This range is directly related to the quality of water that is filtered through the system. Annual maintenance cost of the system is extremely low since the only component that requires replacement is the UV bulb. In addition to the UV bulb being replaced annually, the only other cost of the system is the use of household bleach (Clorox), which is fairly cheap and is easily accessible in many countries. The system is not automated and is controlled by electromechanical timer relays which reduces complexity of the overall design. Since solar panels are used to provide power to the necessary electric components, the system can be operated off-grid.

Table 8: System specifications that satisfy customer requirements

	Standardized Design System Specifications	Customer Requirements
Flow Rate	**10 GPM**	Provide safe drinking water to a community
Gallons of water filtered per day	**10000 Gallons**	
Primary Filtration Mechanisms	**UF Membrane Filtration + UV Disinfection**	Consist of a standardized design that is scalable for different communities
Operation Mode	**Manual**	Consist of simple operational tasks
Annual Maintenance Cost	**$100**	Operate with low costs
Primary Power Source	**Solar**	Operate off-grid
Estimated Design Life	**4-7 years**	Serve a community for a long period of time

6.1.1 Millennium Development Goals (MDGs)

Following the millennium summit of the United Nations in 2000, All United Nations member states and many international organizations set specific goals to improve the well-being of people around the world. The goal set for water was the following:

By 2015, halve the proportion of the population without sustainable access to safe drinking water and basic sanitation by providing access to an "improved water source" and "improved sanitation".

An improved water source is defined as one that by nature of its construction or through active intervention, is likely to be protected from outside contamination, in particular from contamination with fecal matter [23]. Few examples of an improved water source are: protected springs, protected dug wells, and tube wells.

It was declared by the WHO that the world has met the millennium development goal target of halving the proportion of people without sustainable access to safe drinking water in advance of the 2015 deadline, by providing people access to improved water sources. It is important to note that there is still 783 million people without access to clean water globally and 2.5 billion people lack access to improved sanitation [24].
The next development goal for water is currently being discussed. However, the natural and obvious next step, is to provide water to people that meet specific drinking water standards through various purification methods. The purification design presented in this thesis will be a valuable asset in the future when the improved water sources will eventually require purification.

6.2 Conclusions

The proposed design has been implemented in the field by ERAU for the past three years. With three operating systems and successful micro-business startups, there is enough evidence to show that the design in suitable for developing nations. The system specifications meet the general needs of a NGO operating in a developing nation. The filter components eliminate all types of harmful microbiological contaminants, addressing a major health issue that is affecting lives of millions. The design is simple enough to be operated by locals in the commission and area with a high design a life, it is suitable to be used as a permanent water source for communities.

Recommendations

Shipping the purifier over to Haiti has been a major cost factor Project Haiti over the years. The reason for high shipping is due to the weight of the assembly. The stainless steel frame, UF filter and pumps are components that make the design bulky for shipping purposes. A solution for reducing the shipping costs is by making a more modular design. A team of 12 students travel to Haiti to install the purification system each year. If all components of the system could be shipped as airline overweight and oversized luggage, it would still be significantly cheaper than the currently implemented shipping method.

Appendix A

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Appendix B

Journal of Humanitarian Engineering, Accepted for Publication, November 2014

Design and Commissioning of a Community Scale Solar Powered Membrane-Based Water Purification System in Haiti

Design and Commissioning of a Community Scale Solar Powered Membrane-Based Water Purification System in Haiti

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ABSTRACT: *This paper presents the design and commissioning of a solar powered water purification system at the Ryan Epps Home for Children (REHC) in Michaud, Haiti. This system supplies clean drinking water to the 200 children who live and go to school at REHC and also to the community in the form of a micro-business. This micro-business is the mechanism for income generation for sustainable system operation. The purifier uses a three stage filtration system with a disc-type sediment filter, a 0.1 micron ultrafiltration membrane, and an ultraviolet light for disinfection. The backwash cycle extends the life of the ultrafiltration membrane to 4 – 7 years before a new filter is required. Simplicity in operation was an important design consideration because it facilitates local operator training, and understanding. To further ensure complete understanding of operation, a pictorial quick-start manual was developed so that operators only need to follow the diagrams laid out on the manual. The design folder with CAD drawings, schematics, datasheets, and troubleshooting guide are left with the local operators. Testing before shipping and after installation to ensure proper operation upon installation and on-site water quality testing ensures it will promote improved community health.*

Keywords: Community Development, Water Purification, Solar power, Off-grid electricity, Membrane Filtration, WASH Training.

INTRODUCTION

The 7.0 magnitude earthquake that struck Haiti on January 2010 took the lives of over 200,000 people and left 1.5 million people homeless (Lies, 2005). The desperate need for basic necessities such as food and water encouraged Embry-Riddle Aeronautical University (ERAU) students to establish Project Haiti, a student led movement to improve the livelihood of Haitian communities (Tang et al., 2012). Since 2010, ERAU students have designed and installed community scale solar powered water purification systems in various Haitian communities. The initial system installed in Haiti during 2010 was able to provide just 1 gallon per minute (gpm). Since then, the project has evolved immensely and by 2012, ERAU students designed a system capable of providing over 20,000 gallons of water at 20gpm (Wong et al., 2014). The system was installed at Onaville, one of Haiti's largest tent cities, which has a population of about 100,000. This paper presents ERAU's 4th system that was installed at Ryan Epps Home for Children (REHC) during the summer of 2014. The purifier is capable of producing 8,000 gallons of potable water powered entirely from the sun. In addition to providing water for the general operations of the orphanage, ERAU collaborated with local Haitians to implement a micro-business to sell the excess water to surrounding communities to generate income to sustain the purifier. Water, Sanitation and Hygiene (W.A.S.H) training sessions were also performed to educate Haitian comminutes and to improve their general wellbeing.

2 MECHANICAL AND HYDRAULIC DESIGN

2.1 Design Goals

The filtration system provides water for REHC daily operations and the excess water is sold to the surrounding community through a micro-business. Since the system is operated and

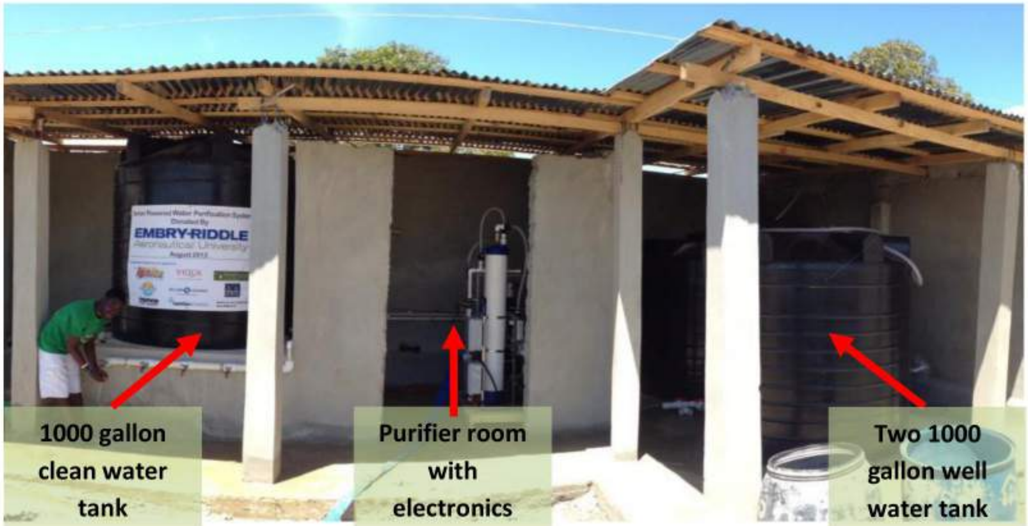

Figure 1: Purification System Layout with Well Water Tanks, Purifier and Clean Water Tank

maintained by people with a limited education background, the main design goal was to accomplish a sustainable design that would require minimal maintenance and simple operational tasks.

The various stages of filtration that the system utilizes were chosen specifically to eliminate the need for cartridge replacement. A system that requires frequent cartridge replacement would be a burden for the Haitian operators in terms of cost. Limited availability in Haiti would also lead to the operators having to import the desired filter cartridges from overseas. For this reason, the main filtration components are backwashable or can be cleaned manually.

Since the system is designed for a community scale, a high flow rate is critical to distribute the potable water effectively. The main filtration mechanism of the purifier is an ultra-filtration (UF) membrane. This allows the system to provide up to 8000 gallons of water per day operating at a high flow rate of 10gpm.

The design excluded the use of complex electronics to avoid maintenance complications in the field. To switch back and forth from filtration mode to backwash mode, the system utilizes a simple valve mechanism which allows for field serviceability. Timers and time-delay relays control the filtration run-time and backwash run-time. Avoiding sensitive electronics has led to a simpler design that is easier to maintain and repair.

2.2 Stages of Filtration

As illustrated in figure 2, the system utilizes three stages of filtration. First, the well water passes through a disc filter which removes sediments larger than 50 micron. As the water passes from the outside of the discs to the inside, grooves molded into the surface of the discs trap the sediments. These discs can be manually cleaned and be reused. A high velocity centrifugal action inside the filter housing causes the sediments to spin away from the disc cartridge to the base of the filter (Leaman, n.d.). The accumulated sediments can then flushed from the filter through the flush port connection at the bottom of the filter. This minimizes the maintenance required on the discs.

0.1 UF membrane filter is used as the second stage filtration. The UF membrane removes all types of bacteria and majority of viruses. The filter has a large surface are of 460ft2 which allows for low transmembane pressure at high flow rates. It also allows the filter to operate for long periods of time before requiring being backwashed. With Proper maintenance, the membrane filter has a 4-7 year design life (Leaman, n.d.).

To eliminate the remaining viruses that pass through the first two stages of filtration, a germicidal ultraviolet (UV) filter is used as the third stage. The UV rays deactivate the DNA of the remaining viruses and the UV bulb provides 9000 hours (375 days) of consistent ultraviolet output before needing to be replaced (Viqua.com, 2014). After passing through the three stages of filtration, the potable water that is distributed meets the drinking water standards set by the Environmental Protection Agency (EPA) and National Sanitation Foundation (NSF).

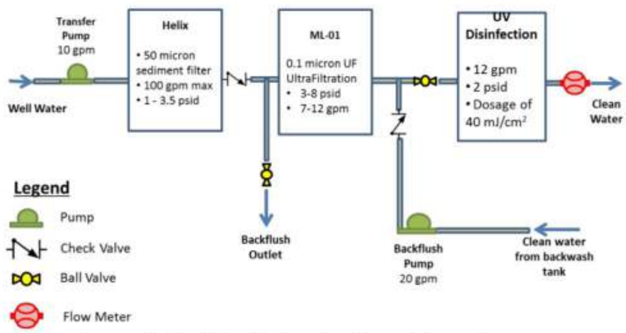

Figure 2: Purifier Hydraulic Flow Schematic

3 PURIFIER OPERATION AND MAINTENANCE

3.1 Modes of Operation

The system operates in two different modes, which are filtration mode and backwash mode. Filtration mode involves passing the well water through the mentioned stages of filtration and the purified water is stored in a clean tank.

3.2 Backwash

After being in operation for a period of time, the suspended particles in the water source form a cake layer on the membrane surface which results in a permeate flux decline or an increase in transmembrane pressure. A backwash system is utilized to lift off the cake layer and flush out the suspended particles.

During backwash mode, purified water mixed with a dosage of chlorine (6 ounces of chlorine to 30 gallons of purified water) is passed through the UF membrane filter in reverse direction. In addition, high velocity air is blown through the filter simultaneously to increase the backwash efficiency.

The use of air sparging during backwash helps to effectively eliminate the cake layer that builds up on the membrane surface. The air improves material removal and also reduces the volume of concentrated foulant to be flushed (Serra et al., 1999).

Chlorine is added to into the backwash to promote chemical breakdown of foulants (Decarolis et al., 2001). Chlorine is able to destroy organic matter that accumulates on the membrane surface and also is capable of repressing microbial growth (Nguyen, 2012). Therefore, the use of chlorine during backwash prevents the formation of biofilm on the membrane surface.

The overall effectiveness of backwashing to enhance membrane productivity is directly related to the characteristics of the well water that is passed through the filter and the frequency at which backwash cycles are performed. For this reason, the system is backwashed every half hour by the Haitian operators. A sequence of timers and time-delay relays controls the half hour of forward filtration then 1 minute of backwash. The timer and relays implement an analog control system repairable in the field. The design includes no additional circuit boards or sensitive electronics to fail while in service.

3.3 Sediment Filter Cleaning

The design of the Helix HD Disc filter is such that a centrifugal action inside the filter spins away sediments from the disc surface towards the flush port at the bottom of the filter. However, the filter discs still require to be rinsed off once a week. The filter is capable of being automatically backwashed once clogged. Implementing a backwash system for the Helix filter requires additional electrical components which complicates the overall design of the system. To retain a simplistic design, Haitian operators are trained on site to manually clean

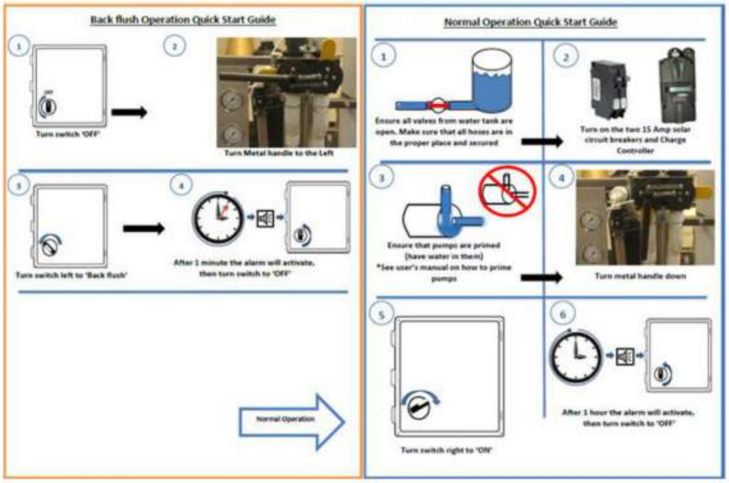

Figure 3: Pictorial Based Quick Start Guide

Figure 4: locals Being Trained with the Aid of Quick Start Guide

the Helix filter by flushing out the sediments trapped between the discs.

3.4 User Manual and Pictorial Guides

After installation, a full day is allocated to train the local operators and to educate them about the functionality of the purifier. To further ensure understanding of operation, the team develops a quick-start pictorial guide. The quick-start guide is designed facilitate the daily operations of the purifier. The operators can simply follow the diagrams laid out on the manual. In addition to the pictorial guides, a technical user manual containing computer aided drawings (CAD), schematics, datasheets and troubleshooting guides were also handed to the operators of REHC. In case the system malfunctions, the user manual contains sufficient information to solve the problem at hand.

4 ELECTRICAL POWER SYSTEM DESIGN

After the earthquake, REHC paid several thousands of dollars to get city power run to the facility. However, Haiti's power grid is extremely unreliable with power available only a couple hours a day, and the cost is extremely expensive at over three dollars per kilowatt-hour (kWh). The ERAU team could not rely on this power source and decided to install two independent solar power systems for purifier operations; one for the well pump and one for the pumps, air blower, and ultraviolet light on the purification system. ERAU team also assisted the installation of a 4kW solar power system for the general REHC facility. This independent power system allows REHC to have a consistent power supply for daily operations of the orphanage. Figure 6 illustrates the solar panel installation layout.

4.1 Well Pump

The well at REHC had been pre-dug to 135 feet several years earlier and a hand pump had been installed on top. To provide enough water for the purification system, a solar well pump had to be installed. The team referred to the well report to ensure that the desired discharge rate would not pump the well dry. Upon arrival, the hand pump was removed and a solar well pump system was installed. The solar well pump system is a battery-less system; water pumps as long as there is solar power available. The solar well pump is a direct current (DC) pump that accepts a wide range of input voltages. This is necessary because the voltage of the solar array, which included four 285 Watt panels, varies depending on sun intensity and cloud cover.

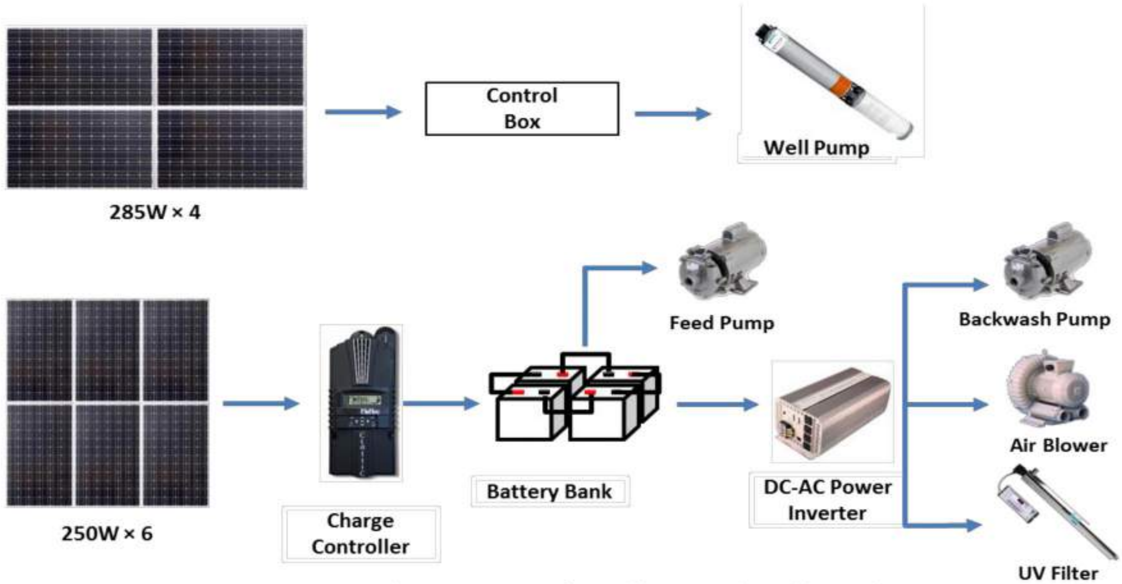

Figure 5: Solar Power System for Well Pump and Purifier Loads

4.2 Purifier Solar System

The design of a solar power system begins with determining the total solar energy required by identifying all power consuming loads, as shown in Table 1.

Table 1: REHC Purifier Loads

Load	Power (Watts)	Hours Needed	Energy (Watt-Hours)
Ultaviolet Filter	43	48	2064
Feed Pump	373	8	2984
Backwash Pump	373	0.13	49.73
Air Blower	373	0.13	49.73
Totals	1162	56.27	5147.47

Dividing the total energy required by 5 hours of peak sun, the theoretical solar power required is 1029.5 watts. Taking into account an 80% temperature de-rating factor, the actual solar power required is 1287 watts. The team ended up purchasing six 250 watt panels, for a total of 1500 watts.

The next step is to determine the battery bank size. The total storage necessary is twice the energy consumption of the system because the battery bank state of charge should not go below 50%. This means that a battery bank capacity of 10,295 kilowatt-hours (kWh) is needed. Using locally sourced Rolls-Surrette S530 deep cycle batteries, each with a voltage of 6V and a capacity of 2.4 kWh, 4 batteries were required to meet the necessary capacity. Connecting these batteries in series provided 24 VDC.
Connecting the solar panels to the battery bank requires the use of a charge controller. A charge controller's main purpose is to regulate the power transfer from the solar panels to the battery and prevents battery overcharging. After comparing products from multiple companies, the MidNite Classic 200 charge controller was chosen for its ability to allow higher battery charging currents over its competitors.

The purifier loads draw their power from the battery bank. However, they required alternating current (AC) power and the battery bank provided DC power. A power inverter, which converts DC to AC, was required. To determine the necessary size, the total power loads needed to be summed and the startup current of the motors needed to be accounted for as well. Since the motors would not be startup at the same time, the motor with the largest startup current would need to be used to spec the inverter. The backwash pump, having the largest startup current of 41 amps, equates to over 4 kW of power draw from the inverter during startup in addition to the roughly 1 kW of power from the other components. After some research, a 5 kW modified sine wave inverter with a 10 kW surge capacity from AIMS was chosen to ensure that no problems in field would occur.

5 PURIFIER TESTING

5.1 Clay Dust Testing

The system was tested at Miller-Leaman Inc, a local water purification company which provided access to their purifier test facilities. Miller-Leaman's engineers and technicians provided critical feedback to improve the overall design of the system. Clay test dust was used to evaluate the performance of the membrane filter during filtration mode and backwash mode. By using test dust ranging from 1-100 microns in size, the team was able to evaluate how the filter performs in filtration and backwash modes. Since UF filters are rated at 0.1 micron, all the clay dust was captured during filtration mode. The water sample was mixed with clay dust to create a sample with a turbidity of 10 nephalometric turbidity units (NTU). After filtering the water sample, the NTU of the backwash water and the filtered water was also measured. The filtered water turbidity was approximately 0.01 NTU. This is the expected result because low turbidity reading means the 0.1 micron membrane effectively excluded the 1-100 micron test dust. The backwash effluent was cloudy and obviously contained the excluded test dust.

5.2 Baseline Pressure Testing

The system utilizes pressure gauges to measure baseline pressures for the Helix disc filter and the UF membrane filter. High turbidity water is passed through the system to purposely clog the filters until the transmembrane pressure increases. The system is then backwashed to confirm that the UF filter's transmembrane pressure drops to its baseline and the Helix disc filter is manually cleaned. The pressure across the UV filter is not measured since it is fairly low.

5.3 Bacteria Testing

After installing the system in Haiti, bacteria tests were performed on a well water sample and a purified water sample to ensure water safety. More than 5 colonies of bacteria are considered an abnormal amount of bacteria and water sanitation or filtration is required (Prolabinc.com, 2014). Figure 3 compares the two samples after 48hours. The well water on the left has sufficient colonies of bacteria to cause illness. After passing through the purifier, not only does the water appear, it has also drastically reduced bacteria levels. The water was then determined as safe for consumption.

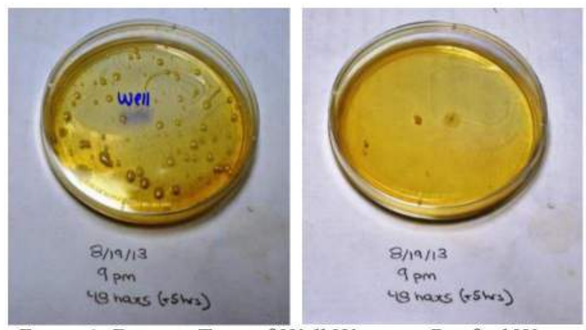

Figure 6: Bacteria Tests of Well Water vs. Purified Water

6 INSTALLATION AND COMMISSIONING

6.1 Installation Partner Criteria

Sustainable development is essential to rebuild Haiti from the 2010 devastation. However, lack of coordination and lack of local ownership leads unsustainable projects. Relief and development efforts require proper management to ensure the success of the project. For this reason, ERAU carefully considers each year's installation partner before committing to the partnership. Each partner is evaluated under the following criteria:

- A US-based organization exists to provide ongoing communication, support, and maintenance

- Representatives in Haiti are available and willing to cooperate and assist pre-trip planning and on-site installation.
- Partner has a sufficient budget prepare for on-site installation prior to our arrival.
- A well is available with a stable bore hole located in a secure area.
- Partner has compatible goals and visions.

6.2 Site Layout

Planning of the site layout began four months before the travel date to Haiti for installation. ERAU students collaborated with representatives of REHC to ensure all requirements were met from both parties. Figure 1 illustrates the purifier system layout and figure 7 illustrates the overall site layout.

The two 1000 gallon tanks are placed to the left of the purifier. The purifier and electronics are stored in a secure enclosure. The 1000 gallon clean water tank is placed on a raised platform so that the purified water can be gravity fed to the distribution rail, eliminating the need for an additional pump. The solar panels were mounted on the roof of a hurricane proof building. REHC has security guards on site at all times. Teaming with a suitable installation partner that meets the criteria facilitates the installation process and also leads to a sustainable project with proper management.

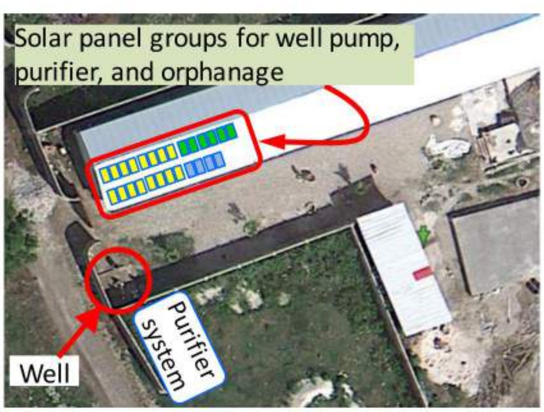

Figure 7: Entire Site Layout with Solar Panels and Purifier System

6.3 Micro-Business

The excess water is sold to the surrounding communities through a micro-business. REHC set up a water selling store front as illustrated in figure 9. Such storefronts are very common in Haitian communities; however when the team collected water samples from competing stores nearby, the water sold in certain stores were not of drinking quality. To encourage the local community to purchase water from a reliable source, REHC sells the water at a cheaper price in comparison to other local water stores nearby. The generated income facilitates the maintenance costs of the purification system. The micro-business has also created multiple jobs in the area.

Figure 8: Water Selling Micro-Business Store Front

7 WATER SANITATION AND HYGIENE (W.A.S.H) TRAINING

Poor sanitation, unsafe water and unhygienic practices are a major cause for disease in developing nations. Despite being preventable, water and hygiene related disease remains one of the most significant child health problems around the world. Diarrhea alone kills over 3,000 children each day and 88% of diarrheal disease is related to unsafe drinking water, inadequate sanitation and poor hygiene (UNICEF, 2014). ERAU utilizes pictorial hygiene posters that are written in Haitian

Creole to educate the local community and children at REHC. Through WASH training, ERAU aims to promote the value of the purification system as well as to attract the local community to purchase the clean water from the REHC micro- business.

8 CONCLUSION

The Project Haiti 2013 team designed and installed a 20gpm water purifier with 1.5hp submersible well pump. The backwash capability of the system allows the main filtration component to be cleaned in place and leads to a design life of 4-7 years. The system consists of a simplistic design with very few custom components. Since the majority of the components used in the system are off-the-shelf, it allows the end user easy access to replace any components in case of failure. By collaborating with an installation partner with a US based organization, ERAU engineers are able to assist in case the system malfunctions due to ongoing communications. Two 1000-gallon tank stores well water for the use of general orphanage operations. One 1000-gallon tanks stores the purified water and is used by the 200 children and staff at the orphanage. The excess water is sold to the local community through a store front located at REHC. The installation of the purification system has also helped to create local jobs in the area. ERAU intends to continue doing similar work in Haiti to provide clean drinking water to those in need.

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Appendix C

2013 ASEE Southeast Section Conference

Project Haiti 2012: Providing an Experiential Learning Experience through the Design and Delivery of a Water Purifier in Haiti

Project Haiti 2012: Providing an Experiential Learning Experience Through the Design and Delivery of a Water Purifier in Haiti

Mr. Yung Wong[1], Mr. Johnathon Camp[2], Mr. Shavin Pinto[3], Mr. Kyle Fennesy[4],

Dr. Marc Compere[5], Dr. Yan Tang[6]

Abstract – In this paper, we share our experiences and lessons learned from Project Haiti 2012, a project to design and install a water purification system serving 20,000 people per day in the largest tent city in Haiti. Project Haiti 2012 was the third and largest system we have built for Haitians and represents a huge success for all participants and stakeholders. This paper discusses the unique experiential learning opportunity involved in the design and delivery of the water purifier in a foreign developing country. Multiple positive educational, social, and economic outcomes were achieved including students applying knowledge gained from coursework towards a greater cause, faculty gaining experience in leading an overseas student trip, engaging Haitians to be less dependent on foreign aid, and relieving water crisis in Haiti. We hope that this paper inspires others to pursue similar experiential learning experiences and develop a repeatable engineering education model for international community improvement projects.

Keywords: Experiential Learning, Water Purification, Humanitarian Development, Engineering Education

INTRODUCTION

The earthquake that destroyed much of Port-au-Prince, Haiti in January 2010 was a rallying point for Embry-Riddle engineering students to help in a hands-on, tangible way. The desperate need for basic necessities like food, water, and shelter motivated the students to respond with a strong desire to help. The student chapter of the American Society of Mechanical Engineers (ASME) promoted the effort and raised funds to build the Project Haiti 2010 water purifier. This unit was based on an earlier Civil Engineering department's senior design project and provided 1 gallon per minute (gpm) of clean water. One student and one faculty from Embry-Riddle joined a larger group's travel for the installation. The following year, Project Haiti 2011, eight students from the Clean Energy Club and faculty designed and installed a purifier system to deliver 4 gpm powered entirely from the sun [Tang, 9]. During the summer of 2012, a team of thirteen installed the Project Haiti purifier delivering 20 gpm in Onaville, one of Haiti's largest tent cities, which has a population of roughly 100,000 Haitians.

Paper Organization

This paper describes, from the students' point of view, Project Haiti 2012's customer needs, design goals, and the resulting system. It also describes the in-field installation and training for local operation and maintenance. It also

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summarizes pedagogical effectiveness based on Kolb's experiential learning theory and success factors, followed by the conclusion and future plans.

PROJECT DESCRIPTION

Background

Project Haiti 2012 began in May 2012 when we received a request of a water purifier from our partner in Haiti: Nehemiah Vision Ministries (MVM), a nonprofit organization focused on transforming the lives of Haitians. We were asked to design and install a water purification system in the largest tent city which had a population of 100,000 people. All of these people, displaced after the earthquake in 2010, live in the foothills outside of Port-au-Prince and rely on NGOs to deliver water. NVM decided to dig a water well and install a water purifier for the people when another NGO, which had previously supplied the water to the area, stopped sending in water trucks for one reason or another. Having only installed systems delivering water no larger than 1200 gallons a day, we jumped on the opportunity to provide approximately 15,000 gallons water every day. We saw this as not only a rewarding experience, but also a major undertaking in engineering, communications, and logistics. We will describe Project Haiti 2012 from the challenging customer needs and our innovative design to the installation and operation.

Customer Needs and Design Challenges

Since the water purification system will be used to serve a large population of 100,000 people who has limited education, the system should be easily operated and need minimum maintenance. The water purification systems we have designed had low flow rate and always consisted of multiple stages that required replacements at least once a year. For such a large system, we did not see these designs to be realistic and sustainable. We decided to design a high flow rate water purification system with components that are backflushable and will last years before replacements are needed.

We also wanted to design a system that was rugged and could be run and maintained by anyone. Since the system was going to a third world country, the end user usually has limited education. Therefore, the system should be easily operated by following a pictorial user guide on a daily basis.

Although these requirements imposed technical challenges on us, the biggest challenge was to raise the necessary funds. We were able to raise approximately $40,000 for hardware and travel support, enough to build a system to serve 20,000 people per day. As a critical installation partner, NVM was responsible for drilling a well as the water source for the water purifier and providing installation and operation equipment such as a fork truck and diesel generator, but we still needed a large amount of funds to build and install the system and support the travel to Haiti for the team of 13 people.

Purifier Design and Testing

The primary technical design goal for the completed installation is achieving 20gpm maximum flow rate. The well pump, the forward and backflush pumps, and filter system are all designed to achieve the target flow rate. The system must be ruggedized and maintainable in-country. This drove the need for analog controls using time-delay relays. The piping system is organized in a way that is clearly visible and traceable for local operation and maintenance. Finally, to avoid the need for expensive replacement filter cartridges, the main filtration components are backflushable. Being backflushable means clean water is pumped in reverse removing all collected debris. This effectively removes the need for replacement cartridges and allows the filters to be cleaned in place.

The main filtration mechanism is a cascade of three different filters. First, well water enters a Disc Filter which gets rid of large debris and sediment down to 50 micron [Miller-Leaman, 5]. As the non-potable water enters the filter housing, a high velocity centrifugal action causes the sediments to spiral way from the disc cartridge to the base of the filter. Water passes from the outside of the disc to the inside and the grooves molded into the surface of the discs. These plastic discs can be removed for manual cleaning then reassembled for reuse.

Next, two 12gpm ultra-filtration (UF) membranes are used in parallel to achieve the 20gpm requirement. This stage eliminates water-borne pathogens larger than 0.1 micron using a size exclusion mechanism. The filter removes all bacteria and some virus. Each membrane is approximately 6 ft. tall with a surface of area of 460ft^2. Such large surface area allows low transmembrane pressure even at their maximum 12gpm. It also allows relatively long intervals of hours or days before backflushing [Miller-Leaman, 10]. With proper backflushing, the hollow fiber membranes have a 4-6 year design life while still meeting drinking water quality requirements.

To deactivate remaining virus the third stage is a germicidal ultraviolet light. The UV bulb is able to provide consistent ultraviolet output for 9000 hours before it needs to be replaced [Viqua, 8]. The ultraviolet energy attacks the microorganisms and destroys the DNA eliminating the ability to function and reproduce. This simple and effective process eliminates 99.99 % of harmful water borne pathogens [Crittenden, 4]. After passing through the three stages of filtration, the potable water that is given out to the public exceeds the drinking water standards set by NSF and EPA.

Normal filtration is straightforward with pumps circulating influent through the three stages. But achieving backflush capability with a simple sequence of valve changes requires careful design. Chemically aided backflush improves filter life so the design adds 6 ounces of chlorine to 30 gallons of purified water during backflush.

In addition to chlorine, air is blown through the filter at high velocity along with the chlorine and water mixture to increase backflush effectiveness. A sequence of timers and time-delay relays controls the 1 hour of forward filtration then 1 minute of backflush. The timer and relays implement an analog control system repairable in the field. The design includes no additional circuit boards or sensitive electronics to fail while in service. The backflush effluent is used by the locals for various applications such as agriculture and construction. Figure 1 illustrates the orientation of filtration components of the system.

The system uses a 25gpm inline pump to transfer unfiltered well water through the purifier. A 15gpm pump and an air blower are used for backflushing the system. These pumps and the blower are powered by a 20kW diesel generator. The UV bulb requires to be switched on at all times since turning the bulb on and off reduces the lifespan of the unit. For this reason, the UV bulb and lighting inside the container are powered using six 235Watt solar panels (Figure 1). The solar panels charge 8 deep cycle batteries which are able to power the UV bulb and the internal lighting continuously for 2 days during the absence of sunlight due to heavy rain or other weather calamities.

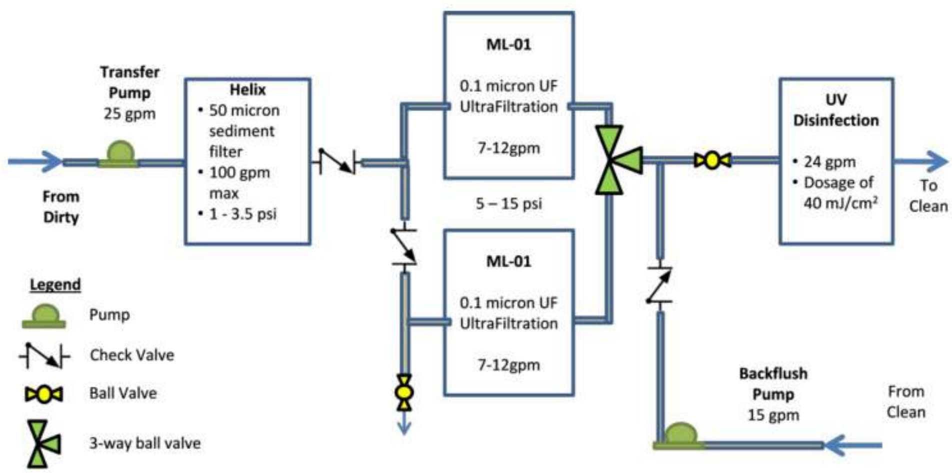

Figure 1 Water Flow Schematic

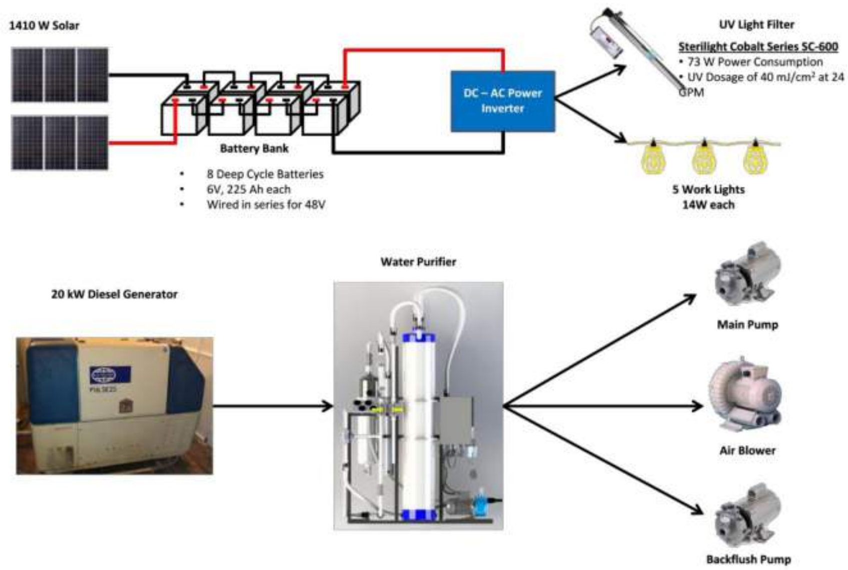

Figure 2 Power System Schematic

The main design goal was to manufacture a system that would be cost effective and highly efficient. A conventional water purification system depends on filter replacements in order to provide potable water. By utilizing the mentioned filter types, we managed to eliminate the need to replace filter cartridges. The UV bulb needs to be replaced after operating continuously for 365days and is the only filter component that requires replacement. The system is able to provide clean drinking water for 20,000 people with minimal maintenance costs.

The system was built and tested in a local water purification company which provided access to their frame fabrication and purifier test facilities. Their engineering and technicians provided valuable feedback and provided a corner of their shop in which to build the system. Once assembled, their wet-floor with water supply, drain, and red clay test dust provided valuable troubleshooting and adjustment prior to shipping the unit to Haiti. Red clay test dust appears similar to talcum powder and provides a known spectrum of particles calibrated between 1 and 100 microns.

Figure 3 Wet Table Testing with Fine Red Clay Dust

The red test dust was used for filter challenge testing on the UF filters. Because the UF filters are rated at 0.1 micron all red test dust was captured in filter mode. This also facilitated backflush mode testing. The wet table is where we finalized the backflush control sequence using air and water for 1 minute (Figure 3).

After installation, two Hach pathoscreen bacteria tests were performed to ensure water safety. After the 48 hour incubation period, side-by-side samples were compared with untreated water (Figure 4).

Figure 4: After 48 hours untreated water (left) indicated bacteria while the purified water (right) indicated no bacteria.

Installation and Training

A team of 13 traveled to Port-Au-Prince Haiti and stayed 5 nights at accommodations provided by NVM. The team was composed of 10 graduate and undergraduate students, 2 professors, one of which was a Haitian translator, and 1 professional engineer. NVM was a critical installation partner providing a fork truck, a flatbed truck, and a 20 kW diesel generator. They also arranged for two 20-foot shipping containers in which to store the purifier and diesel generator. The shipping containers were weatherproof and secure and provided the storage necessary for the purifier, and diesel generator. They also provided secure outdoor space for the solar panels and three 1000-gallon water storage tanks (Figure 5).

Figure 5: Three 1000 gallon tanks stored untreated and treated water. Two with clean, one with well water.

Figure 6: Local women and children lined up far in advance of clean water. This is their best supply of safe, clean water.

Prior to our arrival, NVM drilled a 350-foot well but only had a 1hp pump that provided only 5 gpm. This is much deeper than typical so the Embry-Riddle team brought a 3hp submersible pump increasing flow rate to 25gpm.

NVM provides ongoing oversight of the water purifier installation and used this investment in the Onaville community to start a micro-business selling water. The closest water source prior to this well was 1km away and was prohibitively costly. The free water was farther. All other local sources were likely contaminated. NVM now provides free well water and also sells purified water for a locally competitive price roughly half the cost of the next nearest source. Initial reaction to the purifier's clean water during installation was enthusiastic. Women and children primarily lined up immediately and kept filling buckets late into the night (Figure 6). Reports from Onaville after returning indicate they deliver roughly 3000 five-gallon buckets per day. Each bucket is 5 gallons, so the total water deliverd daily is estimated at 15,000 gallons. The vast majority of that water is unpurified water because it is free. A smaller portion is the purified water for sale. This was an unexpected result and we are still learning each month as we receive reports from NVM about the ongoing operation and maintenance of the system.

We spent five hours training a group of local Haitians how to operate and maintain the system. With the help of our translator and NVM camp manager we are confident of a successful hand-off. We also provided a complete user's manual and maintenance guide and pictorial operation instructions (Figure 7).

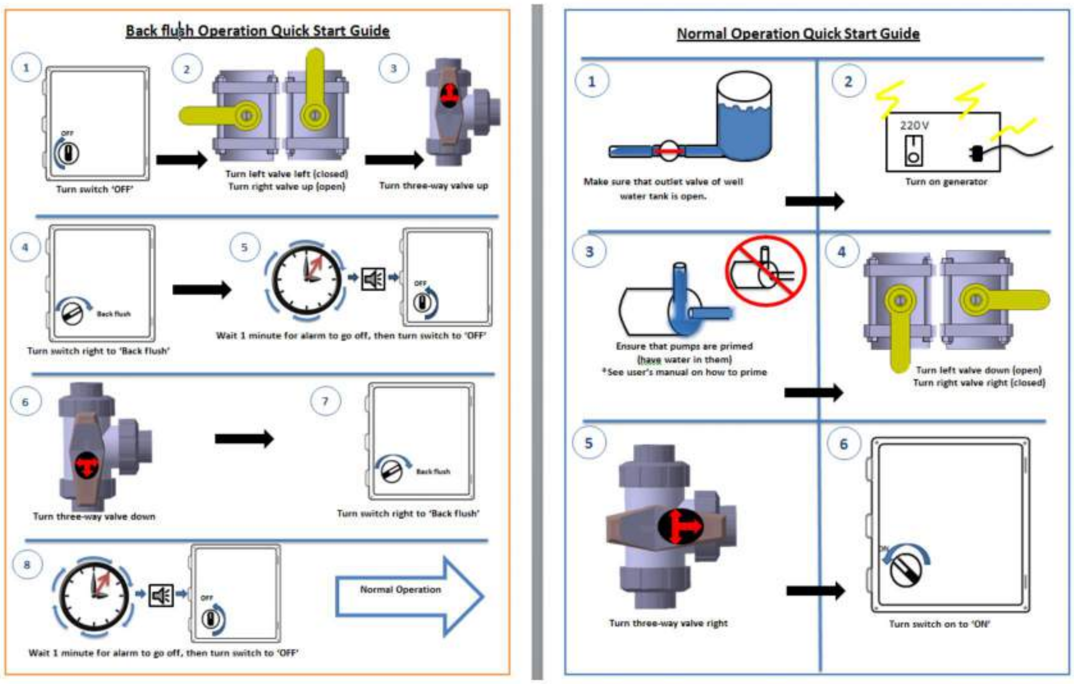

Figure 7: Pictorial Training Manual with Room for Creole Translations

We built the 'Army Jeep' of water purifiers. Its design is straight forward, able to be maintained in the field, has only a few special order components, allows for easy access to most components, and most of the plumbing has quick-connect joints. We are happy to say that, to date, the people of Haiti have been successfully maintaining and operating the system without any problems.

Observations on Growth

Project Haiti has grown as a student-led movement on campus over the past three years mainly as a Clean Energy Club project. It is a movement of students helping students gain access to clean water. The opportunity to help people directly with their engineering skills motivated the students to be successful. The goals in 2011 were to (1) provide the Haitian community with access to improved water, (2) solve a real world problem for a real world customer with real end-users, (3) provide the students' with the opportunity to experience a new culture, (4) increase student awareness of social responsibility, (5) educate new students on water purifier design and public health, (6) fundraise effectively for hardware and travel, and (7) attract prospective students to sustain the project into the future. These formed the basis for goals to achieve in future water purification projects.

Though students did not receive academic credit in 2010 or 2011, they were still extremely motivated as it allowed them to directly help people less fortunate with their engineering skills. The additional goals developed for the 2012 effort were (8) increased local community involvement, (9) to remove the need for replacement filters, (10) to train locals effectively on daily operation, (11) increased Haitian community development, and (12) to receive updates about the system after we left.

We found several of these goals to be in line with guiding principles developed by the Engineers Without Borders (EWB) and the Mortenson Center in Engineering for Developing Communities (MC-EDC), both at the University of Colorado at Boulder [Amadei, 2]. They propose a set of ten guiding principles for humanitarian development projects. Using these as Project Haiti evaluation criteria, our performance has improved over the last three years and still has room for improvement. The comparison in Table 1 below explains how Project Haiti has performed in the most recent 2012 trip using possible grades of *poor*, *moderate*, *good*, or *very good*.

Table 1: Project Haiti Evaluation Against Published Guiding Principles

EWB and MC-EDC Principles	Project Haiti 2012 Grade	Comments
1. Shared mission, vision, values and approach	*Very Good*	All students and sponsors had excellent shared vision.
2. Quality control and ethics	*Very Good*	Financial accountability was high; water pathogen quality achieved US drinking standards.
3. Organizational accountability	*Very Good*	Water system ownership was transferred upon successful installation to local Haitian leaders for long-term oversight and maintenance.
4. Education	*Very Good*	Both graduate and undergraduate students gained academic credit through a Practicum in Water Purification course during the assembly and test phase.
5. Innovation and technological appropriateness	*Very Good*	Plumbing and control electronics were designed for repair in-country with locally available materials.
6. Fundraising	*Moderate*	Project Haiti accomplished the dual purposes of sustainable humanitarian work and student education but raised only 20% of funds required from external sources.
7. Collaboration and teamwork	*Very Good*	Collaboration between internal and external stakeholders was high with the end-user's needs prioritized.
8. Duration of intervention	*Poor*	Project Haiti focused on a new installation site each year.
9. Sustainability	*Moderate*	Previous efforts in 2010 and 2011 did not maintain ongoing local support. Project Haiti 2012's primary installation partner owns and operates the installation site so U.S.-based intervention was replaced with ongoing local support.
10. Evaluation	*Poor*	Peer-team evaluation occurs briefly during the return trip but no third-party evaluation has ever been performed.

As Project Haiti continues to grow, the leadership needs to adopt guiding principles similar to the ones developed by EWB and MC-EDC. These will allow future teams to learn from previous projects, learn how to manage a humanitarian development project effectively, build a sustainably funded effort, and help students grow the project by defining their own specific goals focused on the end-user.

Benefits Gained

The success of Project Haiti 2012 was proved by benefits received by five involved stakeholder groups. First, the Haitians who previously lacked low cost, clean drinking water had their quality of life improved substantially. For most people living in developed countries it's hard to understand the daily reality of not having access to clean, safe drinking water. The Haitians now have access to clean water which improves their health and subsequently allows them to improve their standard of living either through education or more time for earning an income. Second, the engineering students who designed, built, and installed the purifier broadened their experience through a hands-on, collaborative project with a clear goal and deadline. They also broadened their experience through exposure to another language and culture and gained perspective by observing quality of life in a developing country. Third, the university gained positive recognition both in the local community and alumni network through newspaper articles, television interviews and alumni magazine articles. Fourth, the donors and hardware sponsors gained recognition through social media updates, newspaper articles, and also benefitted through tax deductions through the university's non-profit 501c3. Finally, the faculty involved received recognition for service, teaching, and fund raising. Gaining positive recognition is an intangible benefit that generated improves opportunity for both faculty and the associated students.

PEDAGOGICAL EFFECTIVENESS

The collaborative, hands-on nature of the project is a natural part of improving the quality of life for a Haitian community using a team of university students. Hardware fabrication and testing skills were necessary, as were promotion, fundraising, and international coordination and logistics. There was no formal assessment but it is clear from student interviews that the project and installation trip caused learning and growth not found in the classroom. Project Haiti had no formal assessment but qualitative research indicates high levels of personal growth and learning similar to more rigorous double-blind educational experiments [Schlect, 7].

In order to increase the benefits for students through Project Haiti, one faculty developed a course titled Practicum in Water Purification Design as a curricular companion to Project Haiti 2012 so that students could get academic credit for their efforts on pre-installation fabrication and testing. The course was developed through the pedagogical framework based on Kolb's experiential learning theory. As stated in Kolb's experiential learning theory, optimal learning would be achieved through a cycle of four stages (Figure 8) including the Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC), and Active Experimentation (AE) [Abdulwahed , 1, Kolb, 6]. The practicum course's contents and learning activities were designed to focus on stages of CE, RO, and AC while Project Haiti 2012 provided a learning platform of AE.

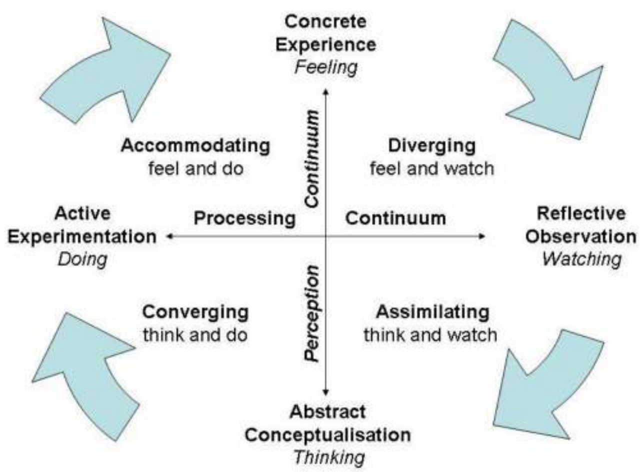

Figure 8 Kolb's Experiential Learning Cycle [3]

Teaching a summer course titled Practicum in Water Purification was a valuable way for both the students and faculty to gain university benefits of a course while developing the purifier. The summer Practicum gave students credit for constructing and testing the system mounting rack, solar power system, purifier components, and backflushing system. This was done partially on campus and partially at a local sponsor company prior to packing and shipping to Haiti. The design, component selection, and sourcing was done prior to the course. Shipping required an uncertain lead time and we chose 3 weeks for transport to Haiti's Port-Au-Prince receiving docks via a commercial shipping company. This left only 3 weeks during the early part of the course for assembly and testing. The scheduled departure on the 7-day installation trip was the day after the summer course ended. During the last 3 weeks of the course we used different water purification components in the lab. During this time we also focused on creating documentation after the purifier shipped. An engineering binder with data sheets for all pumps and purifier components was collected, along with CAD drawings and annotated figures illustrating the main components. A user's manual was developed that included basic installation steps, start-up, stopping, and backflushing steps illustrated using pictorial instructions only (Figure 8).

The Practicum course consisted of lecture session followed by hands-on session. For example, one lecture was to teach water borne pathogens and purification methods. In the hands-on session of the same week, the students immediately performed lab experiments that showed examples of the pathogens just discussed in class. One assignment was to take water samples and grow bacteria from the sample in a petri dish for 3 days. This was done with water test kits less than $15 available at a local hardware store. At the end of the week, students presented photographic records of growth on their water samples after 12, 24, and 36 hours. The assignment also asked them to identify the water-borne pathogen from the bacteria's morphology. This is an ideal case of Kolb's experiential learning model where course material was covered in class, a hypothesis made as to what bacteria might lie in a local pond, an experiment started to grow live bacteria, and the assignment to consider and report on what actually grew on their petri dish. As students presented petri dish photos, we all were surprised at what grew in each sample. Theory, then experimentation over multiple days, then study and presentation of their results completed the example of Kolb's cycle of experiential learning.

SUCCESS FACTORS

Project Haiti 2012 was a big success as all the involved stakeholder groups have gained benefits relevant to their role. We truly realize that the success would be impossible without the academic and financial support from the university administration, industrial partnerships, and community involvement, in addition to having a team of highly motivated students and faculty.

ERAU's administration has provided great support to Project Haiti. In addition to provide half of the funds for hardware and travel support, the administration made a quick approval for the Practicum course to benefit the involved students with class credits which is more attractive than study abroad program. Through Project Haiti 2012, the university gained positive recognition both in the local community and alumni network through newspaper articles, television interviews and alumni magazine articles.

Project Haiti 2012 also motivated corporate sponsors to participate with donations of cash, hardware, or in-kind engineering support when they learned about the project and saw the passion in the students. Their support financially for the other half of funds for hardware and transportation and the in-kind hardware support for filters, solar panels, pumps, and manufacturing validated the theme of the project to be "High Tech, High Touch."

Having installed two previous water purification systems in Haiti, we received widespread local recognition through the local newspaper, television, radio, and was able to present at various luncheons, conferences, and community events. This outreach to the community helped us gain financial and hardware support that were instrumental in helping the project towards successful completion. The community stakeholders helped the students to touch the lives of people who are less fortunate than they are while contributing to solve a world problem.

CONCLUSIONS

Haitians live with chronic illnesses from consuming water ridden with bacteria and viruses. They have no other choice but to drink this bad water. This ongoing project at Embry-Riddle to provide communities in Haiti with access to clean water has changed the lives of many thousands of people. Clean water improves the health of those who consume it, especially children. With improved child health, an entire community and culture improves because their energy level and education will improve. For children and adults, this translates into a higher quality of life, as they can now spend more of their time getting an education, working to make money, and also taking care of their family.

The Project Haiti 2012 team designed, tested, and delivered a 20gpm water purifier with 3hp submersible well pump. The purifier has backflush capability and, combined with locally available chlorine (Clorox) has a design life of 4-7 years. One 1000-gallon tank stores well water for use directly for making concrete or other washing needs.

Two 1000-gallon tanks store the water purifier's output. A faucet rail was constructed to facilitate culturally appropriate bucket filling. The system serves approximately 3000 5-gallon buckets a day. It was installed and stored in a weatherproof, secure shipping container.

The installed purifier has also provided jobs and improved the community immediately. Even before the system was installed, the local leadership began drawing well water to start construction on the compound. The entire interaction with locals was an important educational period for the US-based engineering students. They saw their positive impact on the locals who previously only had access to contaminated water or very expensive clean water.

An annual summer trip to Haiti provides the benefit of known logistics, housing, translation, and security measures. It has provided exceptional learning experiences and positive publicity for the University. Our intention is to continue a yearly trip with university engineering students and trusted Haitian partners so Project Haiti will continue to provide clean drinking to those that desperately need it.

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Yung Wong

Mr. Yung Wong graduated with a Bachelors of Science in Mechanical Engineering, with a concentration in Clean Energy Systems, from Embry-Riddle Aeronautical University in 2012. He is continuing with his Master of Science in Mechanical Engineering with an expected graduation of Spring 2014. He has been a part of the past two water purification systems to Haiti and has held a leadership position in each of those two years. His interests include water purification, renewable energy technology for electricity generation, and project management. He is currently in the process of creating a business focused on designing sustainable water purification systems.

Johnathon Camp

Johnathon Camp is a senior in Mechanical Engineering department who will start his Masters in the fall. He has contributed to the design and implementation of two solar powered water purification systems in Haiti and is a team member supporting the design of solar powered water purification backpack. In addition to water related projects he is also the mechanical team lead for EcoCar2 at ERAU, a developmental program designing a series plug-in hybrid vehicle.

Kyle Fennesy

Mr. Kyle Fennesy is a junior in Mechanical Engineering with a concentration in Clean Energy Systems at Embry-Riddle Aeronautical University. He has previous experience in robotic mobility systems and has worked at Johnson

Space Center for a summer in the Robotic Systems Technology Branch (ER-4) of NASA. He anticipates graduating in December 2015 and plans to attend graduate school at Texas A&M University.

Shavin Pinto

Shavin Pinto graduated with a Bachelors of Science in Mechanical Engineering with a concentration in clean energy systems from Embry-Riddle Aeronautical University in 2012. He will graduate with a Master's of Science in Mechanical Engineering in Fall 2015. Shavin is actively involved in various projects related to clean energy. He is currently a graduate research assistant working on a patent pending design for a portable water purification backpack.

Dr. Marc Compere

Dr. Marc Compere is an Assistant Professor of mechanical engineering at Embry-Riddle Aeronautical University in Daytona Beach, Fla. Compere's current research in sustainable technology focuses on water purification, concentrated solar power for electricity generation, water desalination, and solar powered air conditioning. He has developed and delivered two of Embry-Riddle's solar powered water purification systems to Haiti with university students. His background is in modeling and simulation, hardware-in-the-loop and driver-in-the-loop control systems, robotics, mechatronics, vehicle dynamics, and hybrid electric power system dynamics.

Dr. Yan Tang

Dr. Yan Tang received a B.S. degree and a M.S. degree in automatic control theory and application from Nanjing University of Science and Technology, Nanjing, China, in 1995 and 1999, respectively. She received a Ph.D. degree in mechanical engineering from University of Central Florida, Orlando, Fla., in 2009. She is currently an Assistant Professor in mechanical engineering at Embry-Riddle Aeronautical University, Daytona Beach, Fla. Her research interests include intelligent control, robots, and applications of biomimicry techniques in engineering.

Appendix D

Project Haiti 2013 Technical User Manual

EMBRY-RIDDLE
Aeronautical University

Project Haiti 2013

A 4th Generation ERAU Water Purification System

Serving the Ryan Epps Home for Children

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1. General Points of Information

• Read this entire User Manual before using the water purifier system

• **Do not** run this system over a trans membrane pressure of 14 psi (measured by subtracting <u>UF in</u> pressure from <u>UF out</u> Pressure). This could result in broken components and/or reduce the life span of the system.

• Do not run the purifier system for more than 1 hour without back flushing

• Always double check that your valves are pointed in the correct direction prior to starting the system

• This water purification system is not designed to improve the taste or smell of the water. Purified water can be free of all harmful pathogens yet maintain a taste or odor.

2. System Overview

The 2013 Project Haiti Water Purification System

This is a 3 stage solar powered water purification system. It consists of a Miller-Leaman Helix HD Sediment Filter, a Miller-Leaman Ultra-Pure Ultrafiltration (UF) Membrane Filters, and a Sterilight Cobalt SCM-320 Ultraviolet (UV) System.

3. Installation

To set up the 2013 Haiti Water Purification System for operation:

3.1 Solar System

The UV light is designed to **stay on at all times** (24 hours a day, 7 days a week). Turning the bulb on and off reduces the bulb's lifespan.

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<u>Precautions</u>

• Check all circuit breaker switches are in off position.

• Ensure there are no exposed wires.

• Ensure all wires are connected securely.

<u>3.1.1 Well Pump Solar System</u>

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Major Components

1. Four 285 Watt Solar Modules
2. SunRotor SR-12-110 Pump/Motor
3. SunRotor SRC-M200T Controller
4. SunRotor Low-Water Sensor

Setup

Refer to SunRotor Solar Pump Installation Guide in Section 5 of this binder.

~~3.1.1~~3.1.2 Purifier Solar System

Major Components

1. Six 250 Watt Solar Modules
2. Midnite Solar Classic 200 Charge Controller
3. Midnite MNPV-6 Combiner Box
4. Two Midnite Breaker DC MNEPV15-300, 15 Amp, 300 VDC
5. Midnite Surge Suppressor MNSPD300
6. Four 6V Rolls Surrette S-530's
7. AIMS 5000 Watt 24VDC-to-115VAC Inverter

Setup

1. Wire the six solar panels into two parallel strings with three modules in series in each string.
2. Run these strings to the breakers in the combiner box.

   Warning: Make sure the breakers are in off position.
3. Wire in surge suppressor to combiner box.
4. Connect combiner box with charge controller. (10 awg wire)
5. Connect the four batteries with two parallel strings of two batteries each to create a 24V system. (2 awg wire)
6. Connect battery bank with charge controller. (8 awg wire)
7. Connect battery bank with inverter. (1 awg wire)

Warning: Make sure the polarity is correct on inverter.

8. Turn on the two 15 Amp solar circuit breakers.
9. Charge Controller should be on. Refer to section 7 for the charge controller user manual. The quick start guide is on **page 31** in the manual.
10. Connect loads to inverter.
11. Turn on loads.

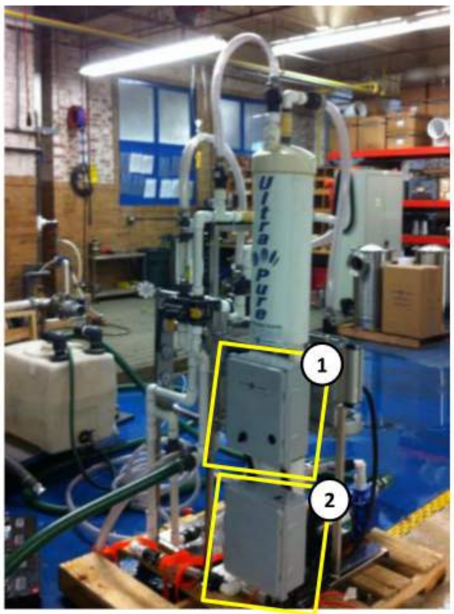
3.2 Plumbing and Pump Priming

1. Make sure that all hoses are in the proper place and secured properly.
   (a) One 1.5" hose should connect the dirty well water tank to the "main" pump
   (b) One 1.5" hose should connect the "main" pump to the side of the sediment filter
   (c) One 1.5" hose should connect the back flush water tank to the "back flush" pump
   (d) A discharge hose should be attached at the bottom of the back flush PVC piping and discharge the dirty back flush water at least 20ft from the system. This is will be harmful waste water, not to be consumed.
2. Ensure that both pumps are primed (have water inside of them). If pumps are not primed, they will break. To prime pumps:
   (a) **Main pump:** to prime the main pump, first have the inlet and outlet hoses connected to the pump. Turn the system on (see normal operation quick start guide section 4.1) for 1-2 seconds then turn the main switch to 'OFF'. Turn the switch to 'ON' for another 1-2 seconds then turn switch to 'OFF'. You should now be able to see water in both the inlet and outlet hoses of the main pump; this indicates that it is primed. If this method does not work and there is no visible water, open Helix inlet end of hose #1(CAD: sheet6/7) and fill the line with water. Then turn the main switch to 'ON' for 1-2 seconds, then 'OFF'.

   (b) **Back flush pump:** to prime the back flush pump, first have the inlet and outlet hoses connected to the pump. Turn the system to back flush (see back flush guide section 4.4) for 1-2 seconds then turn the main switch to 'OFF'. Turn the switch to 'back flush' for another 1-2 seconds then turn switch to 'OFF'. You should now be able to see water in both the inlet and outlet hoses of the main pump; this indicates that it is primed. If this method does not work and there is no visible water, open an end of hose#2 (CAD: sheet 6/7) and fill the line with water. Then turn the main switch to 'back flush' for 1-2 seconds, then 'OFF'.

3.3 Electrical

There are two electrical control boxes for the purifier; one for filtration mode, and one for backflush mode.



Box #1 is the control box for normal filtration mode. This box runs on 24VDC and powers the forward flow pump (Figure 1). Power is drawn from the battery bank.

Figure 1: Ecoinox 2 pump for Filtration Mode

Box #2 is the control box for backflush mode. This box runs on 115VAC and powers the backflush pump, and air blower. Power is drawn off inverter which is connected to the battery bank.

Figure 2: Backflush Pump and Air Blower, respectively

To start system:

1. Make sure that the switch on electrical box #1 is turned off.

   Note: There is only one switch for the system.

2. Ensure that Box #1 is connected to the battery bank.
3. Ensure that Box #2 is plugged into the inverter.

   Note: There is no need to change anything in either box.

4. Make sure the valve is in the correct positioning before turning switch to the **right** for normal filtration, or to the **left** for back flush.

The timer for normal filtration will turn the system off and the alarm on after **60 minutes**, indicating that it is time to backflush the system. There is no need to reset the timer after it turns the system off. The timer for backflush is set at **60 seconds**. The alarm in the secondary control box will turn on after the backflush is done and will not turn off until you turn the main switch to the off position.

4. Modes of Operation

4.1 Normal Operation

1. Turn the steel handle counter clockwise to set the valves in the correct configuration for normal operation.

2. Refer to the Quick-start Guide and make sure that the two yellow valve handles are pointing in the correct direction (left valve pointing downwards, right valve pointing right)*.

3. Turn the switch on the control box to the left towards the label "ON". You should be able to hear the pumps and see the water flowing through the flow-meter and into the clean water tank.

4. After one hour the system will automatically turn itself off. This is normal and means that it is time to back flush the system.

*IMPORTANT: If the yellow valve handles are not 90 degrees apart after turning the steel handle, STOP operation immediately. This indicates that the steel gears have skipped and needs to be set in the correct orientation before resuming operation.

4.2 Turning Off

To turn the filter off, turn the switch on the control box so that it is pointing up towards the label "Off".

4.3 Storage

Storing the system might be necessary if a component is malfunctioning and it will take time for a technician to fix the system. If the system will not be operated for more than 48 hours at a time for any reason, the following procedure is to be used to prepare the system for storage. If the system is not stored properly, then permanent damage may occur or the filters' life span may be reduced. To properly store system:

1. Turn control box to 'OFF'.

2. Turn solar panel circuit breakers off.

3. Turn steel handle clockwise to set the system in Normal flow mode.

4. Close the ball valve (part #4 CAD: sheet 5/7) at the outlet of the inline pump.

5. Add 1 liter of alcohol-based mouth wash (Scope, Listerine, etc.) to the UF membrane filter through the water inlet by removing hose#4(CAD: sheet 6/7).

6. Drain the sediment filter using the flush port valve.

7. Please contact the Embry-Riddle Aeronautical University Project Haiti group if it is necessary to store the system for longer than 1 week. When starting up the system again after storage, reconnect all hoses and electrical connections then run the back flush cycle 10 times before normal operation.

IMPORTANT: If the system will not be operated for over a month, the membrane filter needs to be removed out from the system and be preserved in Meta-Bisulphate (1.5%) or 4L of ethanol, water and glycerin(1:2:1). Preservatives should be refreshed every 6 months. Store the membrane in an controlled environment with temperature between 5°C and 45°C

4.4 Back flush

Backflushing is needed to rejuvenate the UF filters. See section 5 for maintenance schedule. To turn backflush the system:

1. Turn the steel handle clockwise to set the valves in the correct configuration for normal operation

2. Refer to the Quick-start Guide and make sure that the two yellow valve handles are pointing in the correct direction (left valve pointing left, right valve pointing upwards)*.

3. Turn the switch on the control box to the right towards the label "Back Flush". The blower and backflush pump should start automatically. The system is on a timer, so when a back flush cycle is complete, the blower and pump will stop automatically and the alarm will go off.

4.4.1 Membrane Regeneration

Membrane cartridges may experience fouling over time. This may result in a drop in product flow rate and/or an increase in filtration pressure. A regeneration procedure can be performed to reverse this situation.

- **Functional Backflush:** A shock level of 20 ppm of chlorine (3 oz. for 50 gallons) is added to the backflush stream during the backflush cycle and helps prevent further fouling. **Default frequency is once every 24 hours.**
- **Enhanced Backflush:** Add 6 oz. of chlorine to the 50 gallon backflush tank. Backflush once, wait 30 minutes, and backflush one more time. **Default frequency is once a week.**

*IMPORTANT: If the yellow valve handles are not 90 degrees apart after turning the steel handle, STOP operation immediately. This indicates that the steel gears have skipped and needs to be set in the correct orientation before resuming operation.

4.5 Cleaning

4.5.1 Sediment Filter

1. Turn system off and open flush port at the bottom of the sediment filter. Pressure gauges mounted on the filter housing must read zero.

2. Unlatch the band clamp assembly and remove the filter lid.

3. Remove the blue filter cartridge from the filter body. The filtration cartridge seats tightly into the filter body. If necessary, rock the cartridge gently from side to side to facilitate removal.

4. Rinse the exterior of the cartridge in a bucket of purified water to remove any loose debris on the exterior surface of the discs/screen.

5. Unscrew the threaded wing bolt until bolt and cartridge cover plate are loose. Do not remove the wing bolt from the filtration cartridge. The filtration discs will be loose and can freely move on the filtration cartridge frame. Rinse the filtration discs in the bucket of purified water until all contaminants are removed. Restack the discs onto the cartridge frame, position the cover plate and retighten the threaded wing bolt, hand tighten only.

6. Reposition the filtration cartridge into the filter body. Push firmly to seat the o-ring on the cartridge into the filter body.

7. Securely fasten the filter lid to the housing with the stainless steel band clamp.

IMPORTANT: Be sure all particulates have been thoroughly rinsed from the space between discs. Particles caught between discs could affect filtration integrity.

4.5.2 Membrane Filter

See section 4.4 back flush.

4.6 Troubleshooting

4.6.1 Electrical

The system is plugged in but nothing comes on when I turn the switch on.

1. The water level in the well water tanks are too low or clean water tank is full.

   (a) There is a float switch in the well water tank that will turn the system off when the water level is too low in the tank.

   (b) There is another float switch in the clean water tank that will turn the system off if the clean water tank is full. This prevents over filling the tank.

   (c) Wait for water levels to return to appropriate level then try again.

2. There is a blown fuse

   (a) Turn system off.

   (b) Disconnect purifier from battery bank.

   (c) Check fuses with multi-meter. Turn the multimeter to measure resistance (200 W setting). Touch the red wire tip to the top metal part of a fuse. Touch the black wire tip to the bottom part of the same fuse. If the multimeter reads infinite resistance, then the fuse is blown. Pull out with pliers carefully and replace with a new one. If the multimeter reads a small resistance, then that fuse is good. Test the other fuses in the same manner.

   (d) Check electrical connections. Ensure that all wires in the electrical box have not come out of their terminals or are unplugged. Also check exterior wires to see if they have been severed in any way.

3. High current may have tripped overload relays.

   (a) Reset by pushing red reset button on the front of the overload relay inside the control box.

Figure 3: Overload Relay

The UV light is not turning on.

1. Plugs may have come loose.
    (a) Unplug from inverter.
    (b) Make sure that the plug on top of the UV is securely connected.
    (c) Re-plug UV back in the inverter.
    (d) Turn on inverter and see if it is now working

2. Electrical problem with inverter, charge controller, battery bank.
    (a) Ensure the inverter is on and connected to the battery bank. Check the battery voltage. Total battery bank voltage should be roughly 24 VDC. Individual battery voltages should be 6 VDC.

3. After 1 year the UV controller will sound an alarm. If it is August 2014, the life span of the bulb may be expired.

4.6.2 Water Flow

No water is flowing

1. Check the valves are positioned properly (see section 4.1).
2. Check operation switch is in the 'on' position.
3. Make sure the pump is on and primed.

4.6.3 Back Flush

I am trying to back flush the system but nothing is coming out the back flush valve

1. Check valve configurations. For illustrations, see section 4.4. The first yellow valve (on the left) needs to be pointing left. The second yellow valve (on the right) should be pointing up.

2. Water level in clean tank may be too low, tripping the float switch. Stop back flush attempt and run system on normal operation until water level in clean tank rises at least 14 gallons (about two minutes of normal operation).

3. Check that the pump labeled "back flush" is working (i.e. it is vibrating and buzzing).

4. Check that the blower is working (i.e. it is making noise).

5. If none of the above, contact a service technician.

I am back flushing the system but dirty water is going into the sediment filter/ sediment filter pressure gauge is showing a pressure change while back flushing

1. Check valve configurations. For illustrations, see section 4.4.

2. There should not be any activity on the pressure gauge for the sediment filter while back flushing. If there is, then the check valve may be broken. Stop operation and contact service technician.

5. Maintenance Schedule and Log

Time & Date	Maintenance Performed	Name

6. Technical Specifications

Inline Pump	• Ecoinox 2 • 24 VDC, 370 Watts • 1" inlet and outlet	Helix Filter	• 50 micron sediment filter • Clean once a week
Backflush Pump	• AMT 285G-95 • 1 phase, 115 VAC, 1 hp, 12 Amps • 1.25" inlet and outlet	UF Filter	• 0.1 micron hollow fiber membrane filter • Max 14 PSID, 10 – 12 gpm • DO NOT EXCEED 14 PSID
Well Pump	• SunRotor SR-12 • 14.5 gpm @ 135 feet • Voltage Range: 48-120 Volts • 1" FNPT output • 4 inch diameter	Ultraviolet Light Filter	• Sterilight Cobalt SC-320 • 40 mJ/cm^2 @ 10 gpm • 30 mJ/cm^2 @ 13 gpm • DO NOT TURN OFF.
Air Blower	• ½ hp, 115 VAC • 52 cfm @ 0 psi • Max Press. = 2.1 psi	Charge Controller	• Midnite Solar Classic 200 • PV Voc = 224 Volts • Max Output Current = 78 Amps • To add solar capacity, use the MidNite Classic String Sizing Tool
Well Pump Solar Panels	• Four 285 Watt Solar Panels • All four panels in series	Inverter	• 24VDC to 115VAC • 5000 Watt continuous • 10 kilowatt surge
Purifier Solar Panels	• Six 250 Watt Solar Panels • Two parallel strings of three modules in series • Voc = 37.47 V • Isc = 8.76 A	Batteries	• 4 Rolls Surrette S530 Deep Cycle Batteries • 6 V, 400 AH @ 20 HR Rate • All batteries in series

Note: All component data sheets are included in the user manual binder. Refer to those for more information.

7. Glossary

AC	Alternating current
CFM	Cubic feet per minute
Cm2	Centimeters squared
DC	Direct current
FNPT	Female national pipe thread
GPM	Gallons per minute
Imp	Current at max power
Ioc	Short Circuit Current
Lbs.	Pounds
mJ	Millijoules
MNPT	Male national pipe thread
MPa	MegaPascals
Psi	Pounds per square inch
SOC	State of charge
UF	Ultrafiltration membrane. There are two UF filters on this system. They are the tall white cylinders. Can block spores, bacteria, and other pathogens from passing through. Ensures turbidity is below 5 NTU (nephelometric turbidity units).
UV	Ultraviolet light. Deactivates viruses and bacteria when applied in the precise dosage. 00.00.0000
UF	Ultrafiltration membrane. Can block spores, bacteria, and other pathogens from passing through. There are two UF filters on this system. They are the tall white cylinders.
Vmp	Voltage at max power
Voc	Open Circuit Voltage
W	Watts

8. Liability Information

This user manual is for informational purposes only. Embry-Riddle Aeronautical University is not responsible for consequential system damages resulting from misuse of this water purification system or any components delivered or installed by the ERAU team. Reproduction of this manual is prohibited without permission from Embry-Riddle Aeronautical University.

9. Contact Information

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MANN+HUMMEL UA860

(Ultrafiltration Cartridge)

MANN+HUMMEL UA860 cartridge typically removes suspended solids, including high molecular-weight substances such as organic and inorganic compounds. It also acts as a barrier for the control of bacteria, viruses, spores, algae and parasites.

The **MANN+HUMMEL UA860** design is based on years of water filtration expertise, in-house R&D, engineering and manufacturing skills combined with stringent German automotive standards.

Customers use **UA860** to effectively treat surface / borehole water, process water, RO Pre-treatment, to replace conventional filters such as media/sand filters. Above all, **UA860** achieves superior performances in waste water treatment applications, for example with high COD water or oily water.

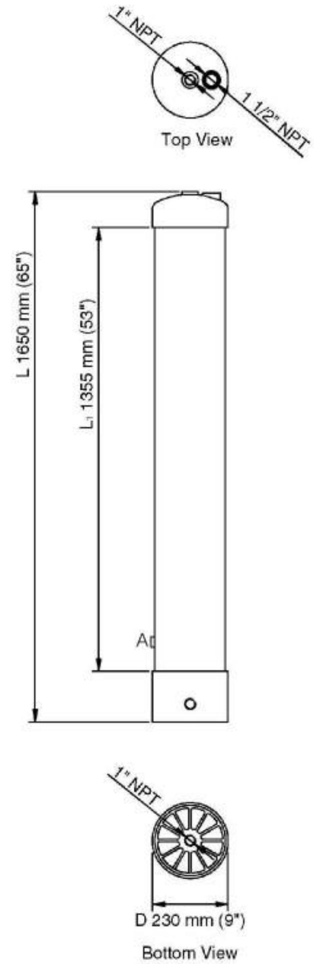
The **UA860** cartridge is designed with these features:
- Hydrophilic / low fouling of membranes
- Flexible flushing modes (Back Flush and Air Scouring)
- High flow rates at low pressure utilization
- Robust fibers producing quality permeate water

Membrane Specifications	
Structure	Hollow Fiber
Membrane Material	Hydrophilic Modified PAN
Surface Area (nominal)	45 m² / 480 ft²
Housing Material	uPVC
Cap & Socket	Glass Reinforced ABS
Potting	Epoxy
Weight (Shipping)	40 kg / 88 lbs

Membrane Performance*	
Filtrate Flux	Up to 80 LMH*
Nominal Pore Size	50 nm
Bacteria Rejection	> Log 6
Feed TSS	Max 350 mg/L
Feed Turbidity	Max 300 NTU

* Depending on feed water quality and operating conditions

MANN+HUMMEL



Legend:

A - 1" NPT Feed

Operating Process Parameter*

Flow Type	Out to In
Filtration	Dead End Mode
Re-generation	Air Scouring with Back Flush
Operating Temperature	Max 45°C / 113°F
Operating TMP	Max 1 bar / 14 psi
Feed Pressure	Max 2 bar / 29 psi
Back Flush	Max 2 bar / 29 psi
Operating pH	From 2 to 10
Back Flush (BF) Flow	Permeate x 1.5 to 2
Air Scouring (AS)	4.2 m^3/h
Air Pressure	From 0.5 to 1 bar / From 7.25 psi to 14.5 psi

Cleaning Process Parameters*

Cleaning Temperature	Max 45°C / 113°F
Chlorine Cleaning	Max 100 ppm
pH Range	From 1 to 10
BF / AS duration	From 30 to 60 seconds

* Depending on feed water quality and operating conditions

Cartridge Storage Conditions:
All cartridges should be preserved in Sodium Meta-Bisulphate (1.5%) or 4L of ethanol, water and glycerin (1:2:1). Preservatives should be refreshed every 6 months. Cartridges are to be stored in controlled environment with temperature between 5°C and 45°C.

Authorized Distributor:

Please contact your nearest MANN+HUMMEL office:

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UAE: +971 4 609 1448
Czech Republic: +420 568 89 8111
Brazil: +55 11 33 78 75 21

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FS-UA860-13-A-EL

Sterilight COBALT

Ultraviolet Water Purification System

Basic

Monitored

The quality of drinking water can change with time and become contaminated with harmful bacteria. The Sterilight Cobalt™ system is a reliable, economical and chemical-free way to safeguard drinking water in any residential application. The Sterilight Cobalt™ system has been designed and tested to ensure quality drinking water is at everyone's finger tips.

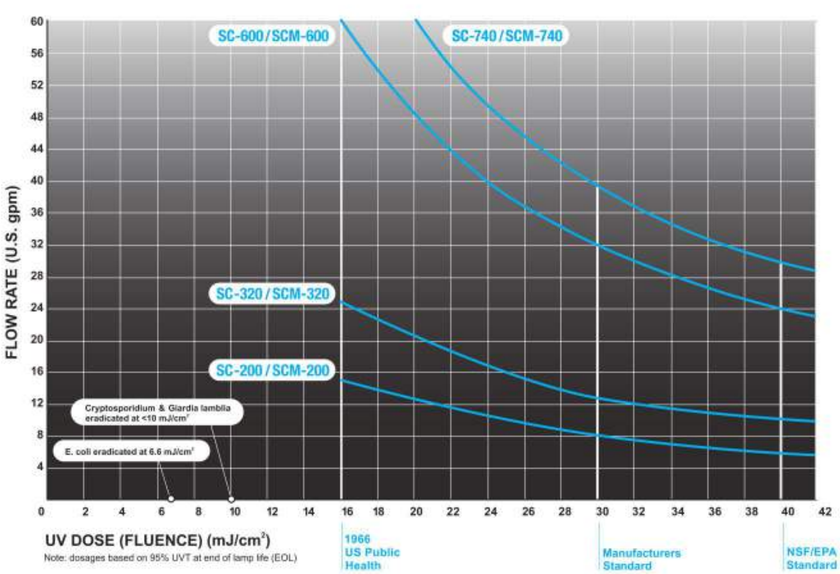
Features of the Sterilight Cobalt UV purification system

- Equipped to inactivate chlorine-resistant parasites such as *Cryptosporidium* and *Giardia*, harmful bacteria like *E.Coli* and viruses not visible to the naked eye.
- Specially designed and tested Sterilume™-HO lamps provide consistent and reliable ultraviolet output over the entire life of the lamp (9000 hours) to ensure continuous purification.
- The system is easy to maintain and service.
- The ultraviolet lamp can be changed without interrupting the water flow.
- Built with a durable stainless steel chamber to prolong life and eliminate ultraviolet light degradation.
- The Cobalt™ ICE power supply visually displays the remaining lamp life and will go into alarm if the lamp fails to notify the homeowner. Monitored systems also have the ability to read the percentage of UV output.
- The power supply has a sealed case to prevent damage from accidental water intrusion and is fully CSA and CE compliant.
- Monitored systems have a specialized 254nm UV intensity sensor which notifies homeowner of changes in UV performance.
- Monitored systems have an optional solenoid valve which will stop the flow of water through the chamber should any changes in the UV performance falls below a safe level.

SPECIFICATIONS

MODEL	SC-200/ SCM-200	SC-320/ SCM-320	SC-600/ SCM-600	SC-740/ SCM-740
FLOW RATES[1]				
US Public Health (16 mJ/cm²)	75.7 lpm (20 gpm) (4.5 m³/hr)	128.7 lpm (34 gpm) (7.7 m³/hr)	227.1 lpm (60 gpm) (13.6 m³/hr)	227.1 lpm (60 gpm) (13.6 m³/hr)
VIQUA Standard (30 mJ/cm²)	37.9 lpm (10 gpm) (2.3 m³/hr)	68.1 lpm (18 gpm) (4.1 m³/hr)	132.5 lpm (35 gpm) (7.9 m³/hr)	158.9 lpm (42 gpm) (9.5 m³/hr)
NSF/EPA (40 mJ/cm²)	30.3 lpm (8 gpm) (1.8 m³/hr)	49.2 lpm (13 gpm) (2.9 m³/hr)	98.4 lpm (26 gpm) (5.9 m³/hr)	117.3 lpm (31 gpm) (7.0 m³/hr)
DIMENSIONS				
Reactor	45.2 cm x 8.9 cm (17.8" x 3.5")	57.9 cm x 8.9 cm (22.8" x 3.5")	78.0 cm x 8.9 cm (30.7" x 3.5")	100.0 cm x 8.9 cm (39.4" x 3.5")
Controller	24.1 cm x 8.1 cm x 6.4 cm (9.4" x 3.2" x 2.5")	24.1 cm x 8.1 cm x 6.4 cm (9.4" x 3.2" x 2.5")	24.1 cm x 8.1 cm x 6.4 cm (9.4" x 3.2" x 2.5")	24.1 cm x 8.1 cm x 6.4 cm (9.4" x 3.2" x 2.5")
Inlet/Outlet Port Size	Combo - 3/4" FNPT/1" MNPT	Combo - 3/4" FNPT/1" MNPT	1" MNPT	1.5" MNPT
Shipping Weight	5.4 kg (12 lbs.)	6.8 kg (15 lbs.)	8.6 kg (19 lbs.)	10.9 kg (24 lbs.)
ELECTRICAL				
Voltage	100-240V./50-60Hz	100-240V./50-60Hz	100-240V./50-60Hz	100-240V./50-60Hz
Power Consumption	35 W	42 W	73 W	88 W
Lamp Watts	27 W	34 W	65 W	80 W
Maximum Operating Pressure	8.62 bar (125 psi)	8.62 bar (125 psi)	8.62 bar (125 psi)	8.62 bar (125 psi)
Ambient Water Temperature	2-40°C (36-104°F)	2-40°C (36-104°F)	2-40°C (36-104°F)	2-40°C (36-104°F)
Lamp Type	Sterilume™ - HO (high-output)			
Visual "Power-On"	Yes	Yes	Yes	Yes
Audible Lamp Failure	Yes	Yes	Yes	Yes
Lamp Replacement Reminder	Yes	Yes	Yes	Yes
Visual Lamp Life Remaining	Yes	Yes	Yes	Yes
Total Running Time	Yes	Yes	Yes	Yes
Chamber Material[2]	304 SS	304 SS	304 SS	304 SS
SCM MODELS ONLY	**SCM-200**	**SCM-320**	**SCM-600**	**SCM-740**
254nm UV Monitor	Yes	Yes	Yes	Yes
Solenoid Output *(solenoid not included)*	Yes	Yes	Yes	Yes
4-20 mA Output	Yes (optional 260134)			

[1] Flow rates stated @ 95% UVT EOL [2] 316 stainless steel available on request



Note: 1mJ/cm² = 1,000 μWsec/cm²

Replacement Parts

- **S200RL-HO** – UV lamp for SC-200/SCM-200
- **S320RL-HO** – UV lamp for SC-320/SCM-320
- **S600RL-HO** – UV lamp for SC-600/SCM-600
- **S740RL-HO** – UV lamp for SC-740/SCM-740
- **QS-200** – quartz sleeve for SC-200/SCM-200
- **QS-320** – quartz sleeve for SC-320/SCM-320
- **QS-600** – quartz sleeve for SC-600/SCM-600
- **QS-740** – quartz sleeve for SC-740/SCM-740
- **410867** – o-ring for all quartz sleeves
- **RN-001** – gland-nut for all systems
- **BA-ICE-C** – electronic ICE controller (100-240V./50-60Hz.)
- **BA-ICE-CM** – electronic ICE monitored controller (100-240V./50-60Hz.)
- **254NM-C1** – UV monitor assembly for Cobalt "Plus" series

Warranty

Please visit www.viqua.com for the comprehensive warranty for our Sterilight product line.

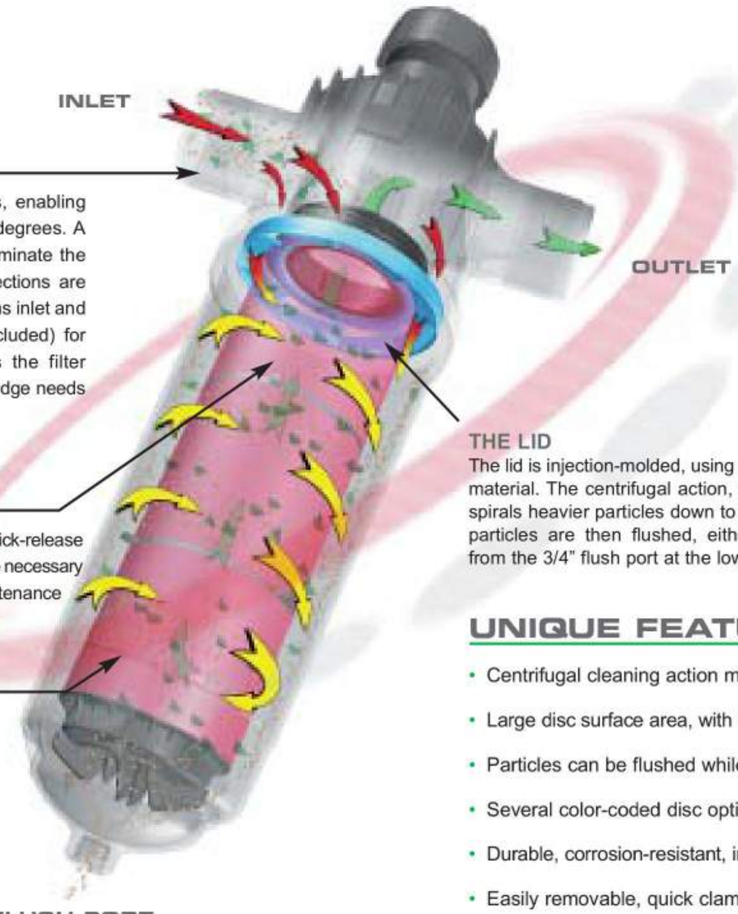
Powered by VIQUA™ A TROJAN TECHNOLOGIES COMPANY

425 Clair Rd. W, Guelph, Ontario, Canada N1L 1R1 • info@viqua.com
t. 1.519.763.1032 • tf. 1.800.265.7246 (US/CAN) • t. +31 73 623 8116 (EUR) • f. 1.519.763.5069



HD SERIES

Miller Leaman's Helix Disc filter models are available in three different sizes: 2", 2" Super and 3". The filters can be installed in any orientation; however, it is preferable to install them in the inverted position (3/4" flush port at bottom). This helps the filtration system work at it's optimum. As water enters the filter housing, a high velocity centrifugal action occurs, spiraling heavier particles (sediment, scale, etc.) away from the disc cartridge, down to the base of the filter. These accumulated particles are then flushed from the filter via the 3/4" flush port connection at the base of the filter (valve not included).



THE BODY
The body contains one inlet and two outlets, enabling the filter to be installed at either 90 or 180-degrees. A threaded cap is supplied with the filter to terminate the outlet port not being used. Inlet/outlet connections are available in NPT or Victaulic. The body contains inlet and outlet pressure gauge ports (gauges not included) for monitoring the pressure differential across the filter element which determines when the disc cartridge needs to be removed for maintenance.

THE CLOSURE
Manufactured in Type 316 stainless steel, the quick-release clamp assembly is strong and reliable. No tools are necessary to remove the clamp and filter cover when maintenance is required.

THE DISC
The three-dimensional disc is ideal for filtering hard particles (such as sediment and scale) and soft fibrous material (such as algae, bugs, cottonwood seed, etc.). The color-coded discs are available in a variety of micron sizes.

THE LID
The lid is injection-molded, using an incredibly strong polyamide material. The centrifugal action, created by the Helix-Element, spirals heavier particles down to the base of the filter. The particles are then flushed, either manually or automatically, from the 3/4" flush port at the lowest point in the lid.

UNIQUE FEATURES

- Centrifugal cleaning action minimizes maintenance
- Large disc surface area, with three-dimensional depth
- Particles can be flushed while filter is in operation
- Several color-coded disc options available
- Durable, corrosion-resistant, injection-molded housing
- Easily removable, quick clamp lid assembly
- Pressure gauge ports molded into housing

HOW IT WORKS

1. Dirty water enters the filter housing through the inlet connection.
2. As dirty water passes through the Helix-Element, the water starts to spin at high velocity. This centrifugal action spins the particles away from the disc media, minimizing manual cleaning frequency.
3. As particles are spun down to the base of the filter, they are flushed via the 3/4" female threaded flush port connection.
4. The dirty water passes from the outside to the inside of the discs. The grooves, molded into the surface of the three-dimensional discs, trap the remaining contaminants in the water.
5. After passing through the discs, the filtered water flows upward and exits the filter through one of the outlets. The outlet not being used is terminated with a threaded cap.

MILLER-LEAMAN
INCORPORATED

800 Orange Avenue • Daytona Beach, Florida 32114 • www.millerleaman.com
TEL 386.248.0500 • FAX 386.248.3033 • TOLL FREE 800.881.0320
EMAIL sales@millerleaman.com

HD SERIES

TECHNICAL DATA

Flow Rates for a Single Filter Housing
2"/100 GPM Max.*
2" Super/100 GPM Max.*
3"/200 GPM Max.*
Multiple pods are manifolded for higher flow rates
* Maximum flow rates should be derated for high solids loading, particularly for finer disc media.

Pressure Rating
All units rated to 125 PSI

Temperature Rating
All units rated to 140° F

Inlet/Outlet Configurations
2" and 3" models available with NPT and/or Victaulic inlet/outlet connections
In-line and 90-degree configurations standard
(Filter is supplied with a cap for outlet port not being used)

Construction Materials
Housing: Polyamide
Discs: Polypropylene
Gaskets: EPDM
Filter Pod Clamp: Stainless Steel (Type 316)

Micron Options Available
- 200 Micron (80 Mesh)
- 100 Micron (150 Mesh)
- 130 Micron (120 Mesh)
- 50 Micron (250 Mesh)

Please contact your distributor about modular capabilities.

Filter Components
A. BAND-CLAMP ASSEMBLY
B. REMOVABLE FILTER LID
C. FILTER BODY
D. MICRON/MESH DATA PLATE
E. OUTLET GAUGE PORT (GAUGE NOT INCLUDED)
F. INLET GAUGE PORT (GAUGE NOT INCLUDED)
G. FILTER DISC CARTRIDGE
H. HELIX-ELEMENT
I. O-RING SEAL
J. CARTRIDGE COVER PLATE
K. THREADED WING BOLT
X. SEE TABLE BELOW
Y. SEE TABLE BELOW
Z. SEE TABLE BELOW

MODEL N MBER	MODEL T PE	INLET/O TLET SI E T PE	FILTER S RFACE AREA (S . IN.)	FL SH PORT CONNECTION SI E	MAXIM M FLO (GPM)	MAXIM M PRESS RE RATING (PSI)	X		(SEE DI
HD -2NA-*	Regular	2"/NPT	186	3/4"	100	125 PSI	12 1/8"	24 1/8"	18"
HD -2SA-*	Super	2"/NPT	263	3/4"	100	125 PSI	12 1/8"	28 3/4"	22 15/16"
HD -3NA-*	Regular	3"/NPT	263	3/4"	200	125 PSI	13 1/4"	30"	22 15/16"
HD -2NW-*	Regular	2"/Victaulic	186	3/4"	100	125 PSI	12 1/8"	24 1/8"	18"
HD -2SW-*	Super	2"/Victaulic	263	3/4"	100	125 PSI	12 1/8"	28 3/4"	22 15/16"
HD -3NW-*	Regular	3"/Victaulic	263	3/4"	200	125 PSI	13 1/4"	30"	22 15/16"

* 50, 100, 130,& 200 micron options available. Please specify disc size when ordering. Example: HD-2SA-130 = 2" NPT Super with 130 - micron discs.

** Disc cartridges for 2" regular models (HD-2NA and HD-2NW) and 2" super models (HD-2SA and HD-2SW) vary in size. The cartridge for the 2" regular models is 15.5" in height; The cartridge for the 2" super models is 20.5" in height. This means that the 2" super models have approximately 40% more surface area for filtration (186 sq. inches vs. 263 sq. inches).

ECOJET - ECOINOX - JET

EL/POMPE AUTOADESCANTI
SERIE "ECOJET-ECOINOX-JET"

SELF-PRIMING EL/PUMPS
"ECOJET-ECOINOX-JET" SERIES

ECOJET B

ECOINOX

JET B

APPLICAZIONI:
Lavaggio catene, antincendio, sollevamento acqua per autoclavi, gruppi di condizionamento e alimentazione WC.
ECOJET BB – JET BB: Ideali per tutti quei servizi dove è necessario l'utilizzo di acqua di mare.

APPLICATIONS:
Chain washing, fire fighting, water pressure system, conditioning systems, WC supply.
ECOJET BB – JET BB: Suitable for all services where it's necessary to use sea water.

COSTRUZIONE:
ECOJET BB- JET B: corpo pompa completamente in bronzo, diffusore e venturi in policarbonato, girante in lega speciale d'ottone, albero in Acciaio Inox AISI 316 e tenuta leccatina di alta qualità in Ceramica, Grafite Inox
ECOJET B: Corpo pompa in bronzo con supporto in acciaio INOX, diffusore e venturi in policarbonato, Girante in lega speziale d'ottone, albero in Acciaio Inox AISI 316 e tenuta leccatina di alta qualità in Ceramica, Grafite Inox
ECOINOX: Corpo pompa completamente in Acciaio Inox AISI 304, diffusore e venturi in policarbonato, girante in tecnopolimero, albero in Acciaio Inox AISI 316 e tenuta leccatina di alta qualità in Ceramica, Grafite Inox

CONSTRUCTION FEATURES:
***ECOJET BB - JET B**: Bronze body pump, diffuser and venture made in polycarbonate, brass impeller, shaft in stainless steel AISI 316 and high quality ceramic-NBR mechanical seal.*
***ECOJET B**: Totally bronze body pump with stainless steel support, polycarbonate diffuser and venturi, brass impeller, shaft in stainless steel AISI 316 and high quality ceramic-NBR mechanical seal.*
***ECOINOX**: Totally AISI 304 stainless steel body pump, polycarbonate diffuser and venturi, brass impeller, shaft in stainless steel AISI 316 and high quality ceramic-NBR mechanical seal.*

MOTORI:
Isolamento: . . . . Classe "F"
Protezioni: . . . . "IP 22" per C.C. ; "IP 54/55" per C.A.
Tensioni: . . . . 12 V C.C.; 24 V C.C.;
. . . . .230V 1~ ; 230/400V 3~ C.A. 50Hz

MOTORS:
Insulation: . . . . "F" Class
Protections: . . . . "IP 22" for D.C. ; "IP 54/55" for A.C.
Voltages: . . . . .12 V D.C.; 24 V D.C.;
. .230V 1~; 230/400 V 3~ A.C. 50Hz

GENERALITA':
Elettropompe autoadescanti a getto con diffusore venturi e girante chiusa, hanno un eccezionale capacità di autoinnesco (fino a 8 metri verticali).
Solo al primo avviamento o dopo un lungo periodo di inutilizzo si rende necessario il riempimento del corpo pompa, in seguito, anche con il tubo di aspirazione vuoto adescano automaticamente.
Si consiglia di installare sulla bocca di aspirazione un filtro ed una valvola a clapet.

GENERALITY:
The Jet self priming electro pump with diffuser and venture pipe and closed impeller, have an outstanding self-priming capacity (up to 8 m vertical).
Only at the first start or after a long term disuse, it is necessary to fill the body pump with water then, also with the suction pipe empty, the pump primes.

We suggest to install a filter and a clapet valve on the suction pipe.

GARANZIA:
Due anni (vedi condizioni generali di vendita)

WARRANTY:
Two years (see our general sale conditions)

PRESTAZIONI: / *PERFORMANCE:*

Versione in C.C.
Tensione 12 – 24 V

D.C. Version
Voltage 12 – 24 V

EL/POMPA *EL/PUMP*	CORPO POMPA *BODY PUMP*	POT. *POWER*	ASSORB. *ABSOR.*	TENSIONE *VOLTAGE*	GIRI/1'	PORTATA l/min						*DELIVERY l/min*				
						5	10	20	30	40	50	60	70	80	90	100
						PORTATA m3/h						DELIVERY m3/h				
						0.3	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6
		kW	A	V	RPM	PREVALENZA TOTALE m H_2O						*TOTAL MANOMETRIC HEAD m H_2O*				
ECOJET 1	B-BB	0.30	30	12	2900	26	23	18	14	8	3					
ECOJET 1	B-BB	0.30	19	24	2900	28	24	20	16	10	5					
ECOJET 2	B-BB	0.37	24	24	2900	35	30	25	19	14	8					
ECOINOX 1	I	0.30	30	12	2900	26	23	18	14	8	3					
ECOINOX 1	I	0.30	19	24	2900	28	24	20	16	10	5					
ECOINOX 2	I	0.37	24	24	2900	35	30	25	19	14	8					
JET 3	B	0.55	36	24	2900	42	39	32	30	25	20	15	5			
JET 4	B	0.75	42	24	2900	35	33	30	28	24	20	17	15	12	10	
JET 4R	B	0.85	55	24	2900			38	36	34	33	32	28	26	25	
JET 518	B	1.1	60	24	2900	47	45	42	39	37	35	33	31	29	27	25

PRESTAZIONI: / *PERFORMANCE:*

Versione in C.A.
Tensione 230V 1~ 50 Hz
Tensione 230/400V 3~ 50Hz

50 Hz A.C. Version
Voltage 230V 1~ 50 Hz
Voltage 230/400V 3~ 50Hz

EL/POMPA *EL/PUMP*	CORPO POMPA *BODY PUMP*	POT. *POWER*	TENSIONE *VOLTAGE*	GIRI/1'	PORTATA l/min								*DELIVERY l/min*						
					5	10	20	30	40	50	60	70	80	90	100	110	125	140	160
					PORTATA m3/h								DELIVERY m3/h						
					0.3	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0	6.6	7.5	8.4	9.6
		kW	V	RPM	PREVALENZA TOTALE m H_2O								*TOTAL MANOMETRIC HEAD m H_2O*						
ECOJET 2	B-BB	0.50	230V 1~ 230/400V3~	2900	36	31	24	20	17	15									
ECOINOX 2	I	0.50	230V 1~ 230/400V3~	2900	39	31	24	20	17	15									
JET 3	B	0.55	230V 1~ 230/400V3~	2900	49	45	39	34	29	25									
JET 4	B	0.75	230V 1~ 230/400V3~	2900	41	39	35	31	29	26	23	20							
JET 518	B	1.1	230V 1~ 230/400V3~	2900	50	49	45	42	40	38	36	34	32	30	28				
JET 522	B	1.1	230V 1~ 230/400V3~	2900	37	36	33	32	31	29	28	27	25	24	23	21	20	17	15
JET 618	B	1.5	230/400V3~	2900	66	65	61	57	55	51	48	45	42	40	36				
JET 622	B	1.5	230/400V3~	2900	53	52	49	47	46	44	43	41	40	39	36	35	32	30	27
JET 722	B	2.2	230/400V3~	2900	61	60	57	55	54	52	50	49	47	45	44	42	39	37	34

Note: prestazioni secondo EN ISO 9906/ *Notes: performances in accordance with EN ISO 9906*

NOTE:
Dati ricavati in sala prove con altezza di aspirazione pari a un metro
Su richiesta è possibile avere la versione a 60 Hz

NOTE:
Technical data obtained in test condition with 1 m of suction head
On request we can supply 60Hz version

LEGENDA:
BB – Corpo pompa completamente in bronzo
B – Corpo pompa in bronzo con supporto in acciaio INOX
I – Corpo pompa completamente INOX

LEGEND:
BB – Totally bronze body pump
B- Totally bronze body pump with stainless steel support
I – Totally INOX body pump

DIMENSIONI E PESI IN: *DIMENSION AND WEIGHT :*

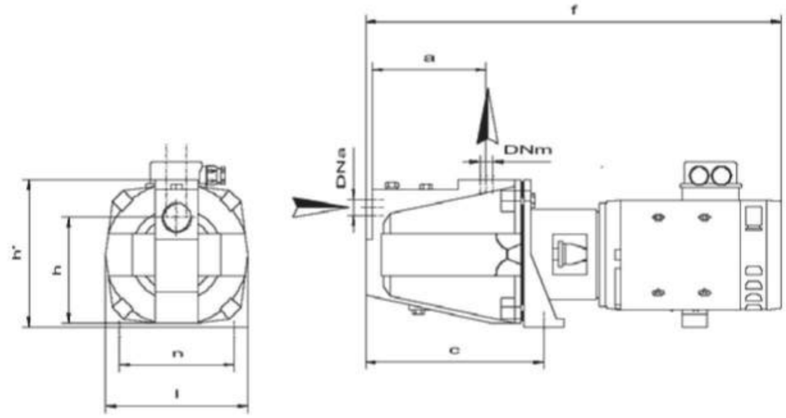
Corrente continua *Direct Current*

ELETTROPOMPA *EL/PUMP*	a	c	h	h'	f	n	l	DNa	DNm	Kg
ECOJET 1	111	145	130	158	400	124	160	1''	1''	11
ECOJET 2	111	145	130	158	400	124	160	1''	1''	12
ECOINOX 1	100	185	125	180	360	124	160	1''	1''	6
ECOINOX 2	100	185	125	180	360	124	160	1''	1''	7
JET 3	130	230	150	195	480	155	185	1''	1''	23
JET 4	130	230	150	195	485	155	185	1''	1''	24
JET 4R	130	230	150	195	490	145	185	1''	1''	28
JET 518	160	275	165	225	630	175	215	1'' ½	1''	39

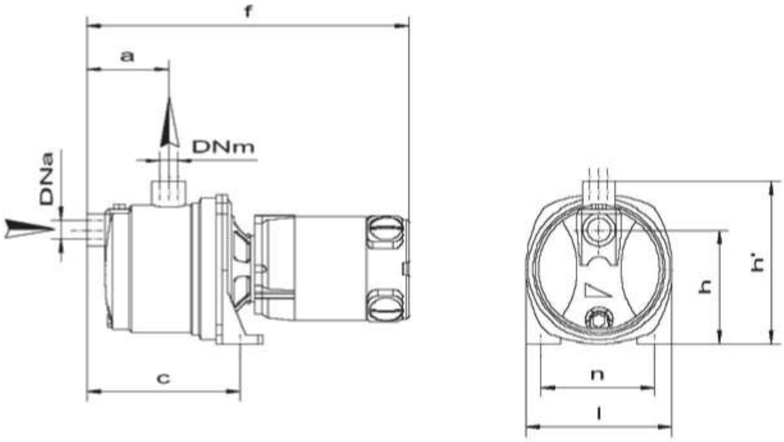
Corrente alternata 230V 1~, 230/400V 3~ *Alternating Current 230V 1~, 230/400V 3~*

ELETTROPOMPA *EL/PUMP*	a	c	H	h'	F	n	l	DNa	DNm	Kg
ECOJET 2	111	145	130	158	390	124	160	1''	1''	11
ECOINOX 2	100	185	130	158	360	124	160	1''	1''	6
JET 3	130	230	150	195	430	155	185	1''	1''	21
JET 4	130	230	150	195	460	155	185	1''	1''	22
JET 518	160	275	165	225	570	175	215	1'' ½	1''	32
JET 522	160	275	165	225	570	175	215	1'' ½	1''	32
JET 618	160	275	165	225	570	175	215	1'' ½	1''	34
JET 622	160	275	165	225	570	175	215	1'' ½	1''	34
JET 722	160	275	165	225	570	175	215	1'' ½	1''	35

Nota: Le dimensioni sono indicative. Misure in mm / *Notes: Dimensions are approximated. Dimensions in mm*



ECOJET - JET



ECOINOX

3/4" & 1" Self-Priming Utility Pumps

Model 2851-96
Aluminum

Model 4292-96
Cast Aluminum

Model 4850-97
Cast Bronze

Model 2851-96

- **Aluminum Construction**
- **Viton® Mechanical Seal and O-Ring**
- **1" NPT Suction and Discharge Ports**
- **1/3 HP ODP Motor with 8 Ft. 115 VAC Power Cord**
- **Two Garden Hose Adapters and Carry Handle Included**
- **Self-Cleaning Impeller**
- **Maximum Suction Lift 15 Ft. Without Foot Valve**

AMT Model 2851-96 is designed for liquid transfer and general dewatering such as: emergency water supply, storm drains, pool/spa tub drainage and select chemical transfer up to 1.6 specific gravity that are compatible with all pump components.

Model 4292-96

- **Cast Aluminum Construction**
- **Buna-N Mechanical Seal and O-Ring**
- **1" NPT Suction and Discharge Ports**
- **Two Garden Hose Adapters and Carry Handle Included**
- **1/2 HP NEMA 56J Open Drip Proof (ODP) Motor with 8 Ft. 115 VAC Cord**
- **Maximum Suction Lift 6 Ft.**

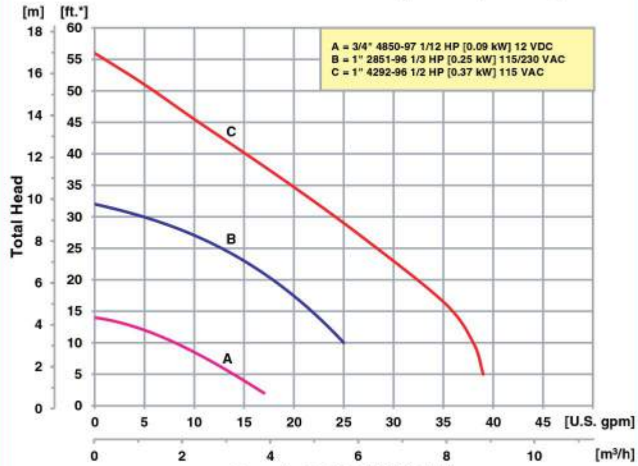
AMT Model 4292-96 is designed to be portable and handle many water transfer services including: storm drainage, emergency water supply, wash down and pool/spa tub draining. Self-cleaning, semi-open impeller handles solids up to 1/8" diameter.

Model 4850-97

- **Cast Bronze Construction**
- **Buna-N Mechanical Seal and O-Ring**
- **3/4" NPT Suction and Discharge Ports**
- **1/8 HP, 12 Volt DC, 3700 RPM Motor**
- **Maximum Suction Lift 4 Ft.**

The AMT Model 4850-97 Self-priming Bronze Centrifugal pump is compact and designed for a wide range of dewatering/recirculating applications including: marine, salt water aquaculture and live well tanks. Meets U.S. Coast Guard (USCG) Electrical Standards (Title 33, Chapter 1, Part 183, Subpart 1) for Ignition Protection on Gasoline Powered Vessels.

Performance of Self-Priming Utility Pumps



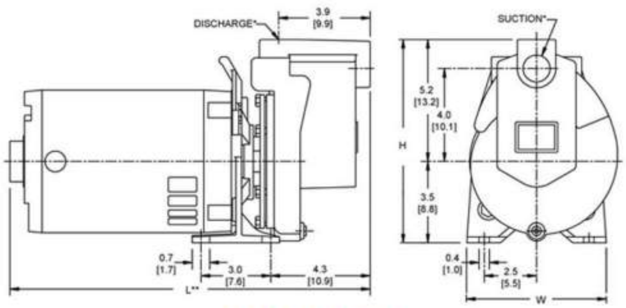
(*)Convert to psi, divide by 2.31 Liquid - Water specific gravity 1.0

AMT®
A Gorman-Rupp Company
400 Spring Street • Royersford, PA 19468 USA
www.amtpump.com • 888-amt-pump (268-7867)

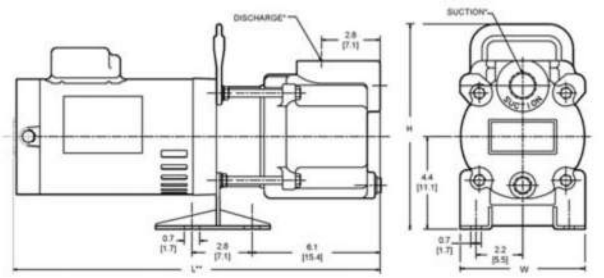
For use with nonflammable liquids compatible with pump component materials. Viton® and Teflon® are registered trademarks of E. I. Dupont.

Self-Priming Utility Pumps

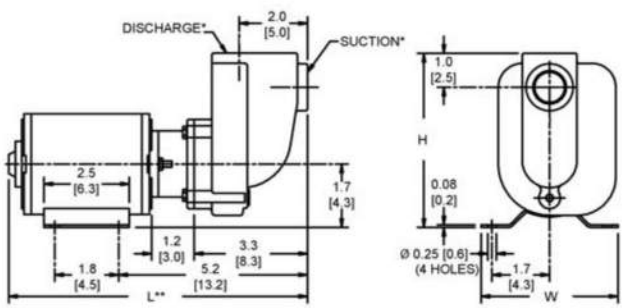
Pump Dimensional & Specification Data



Model 4292-96



Model 2851-96



Model 4850-97

Model	Curve	HP	PH	ENC	Voltage @ 60 Hz	Full Load Amps	SUC*	DIS*	L**	W	H	Ship Wt. (Lbs.)
4292-96	C	1/2	1	ODP	115	10	1	1	16.1 [40.8]	6.5 [16.5]	8.7 [22.0]	30
2851-96	B	1/3	1	ODP	115/230	8/4	1	1	17.6 [44.7]	6.0 [15.2]	9.8 [24.8]	39
4850-97	A	1/8	–	TENV	12.8V DC	11	3/4	3/4	8.7 [22.0]	4.0 [10.1]	5.1 [12.9]	9

(*) Standard NPT (Female) pipe thread.
(**) This dimension may vary due to motor manufacturer's specifications.
NOTE: Dimensions are in inches (centimeters) and have a tolerance of ± 1/4".

Standard Features

Model 4292-96

- Cast Aluminum Construction
- Buna-N Mechanical Seal and O-ring
- 1" NPT Suction and Discharge Ports
- Maximum Working Pressure 75 PSI
- 1/2 HP NEMA 56J Open Drip Proof (ODP) Motor with 8 Ft. 115 VAC Power Cord
- Maximum Temperature 180° F
- Maximum Suction Lift 6 Ft.
- (2) NPT Garden Hose Adapters and Carry Handle Included
- QSP – Quick Ship Pump

Model 2851-96

- Aluminum Construction
- Viton® Mechanical Seal and O-ring
- 1" NPT Suction and Discharge Ports
- Maximum Working Pressure 75 PSI
- 1/3 HP Open Drip Proof (ODP) Motor with 8 Ft. 115 VAC Power Cord
- Maximum Temperature 180° F
- Self-cleaning Impeller
- Maximum Suction Lift 15 Ft.
- (2) NPT Garden Hose Adapters, Base and Carry Handle Included
- QSP – Quick Ship Pump

Model 4850-97

- Cast Bronze Construction
- Buna-N Mechanical Seal and O-ring
- 3/4" NPT Suction and Discharge Ports
- Maximum Working Pressure 50 PSI
- 1/8 HP, 12 Volt DC Motor
- Maximum Temperature 180° F
- Maximum Suction Lift 4 Ft.
- QSP – Quick Ship Pump

Hazardous Duty/Xplosion Proof motors available from stock ranging from 1 to 10 HP;
CALL FOR QUOTATION & LEAD TIME!

AMT A Gorman-Rupp Company

Manufacturer of AMT & IPT Pumps
400 Spring Street • Royersford, PA 19468 USA
www.amtpump.com • 888-amt-pump (268-7867)

Standard Single-Stage High-Flow Air Blower

115/208-230 VAC, 1-Phase, 52 CFM at 0 PSI, 1/2 hp

Single-Stage Blower

In stock
$660.64 Each
9960K54

Also known as regenerative blowers, vortex blowers, side-channel blowers, and ring compressors, these blowers deliver high air flow rates at low pressure. They can operate as either a blower or vacuum pump. All have a high-speed rotating impeller that regenerates or compresses air inflow with each revolution. Great for drying, aeration, air-powered conveying, and spraying.

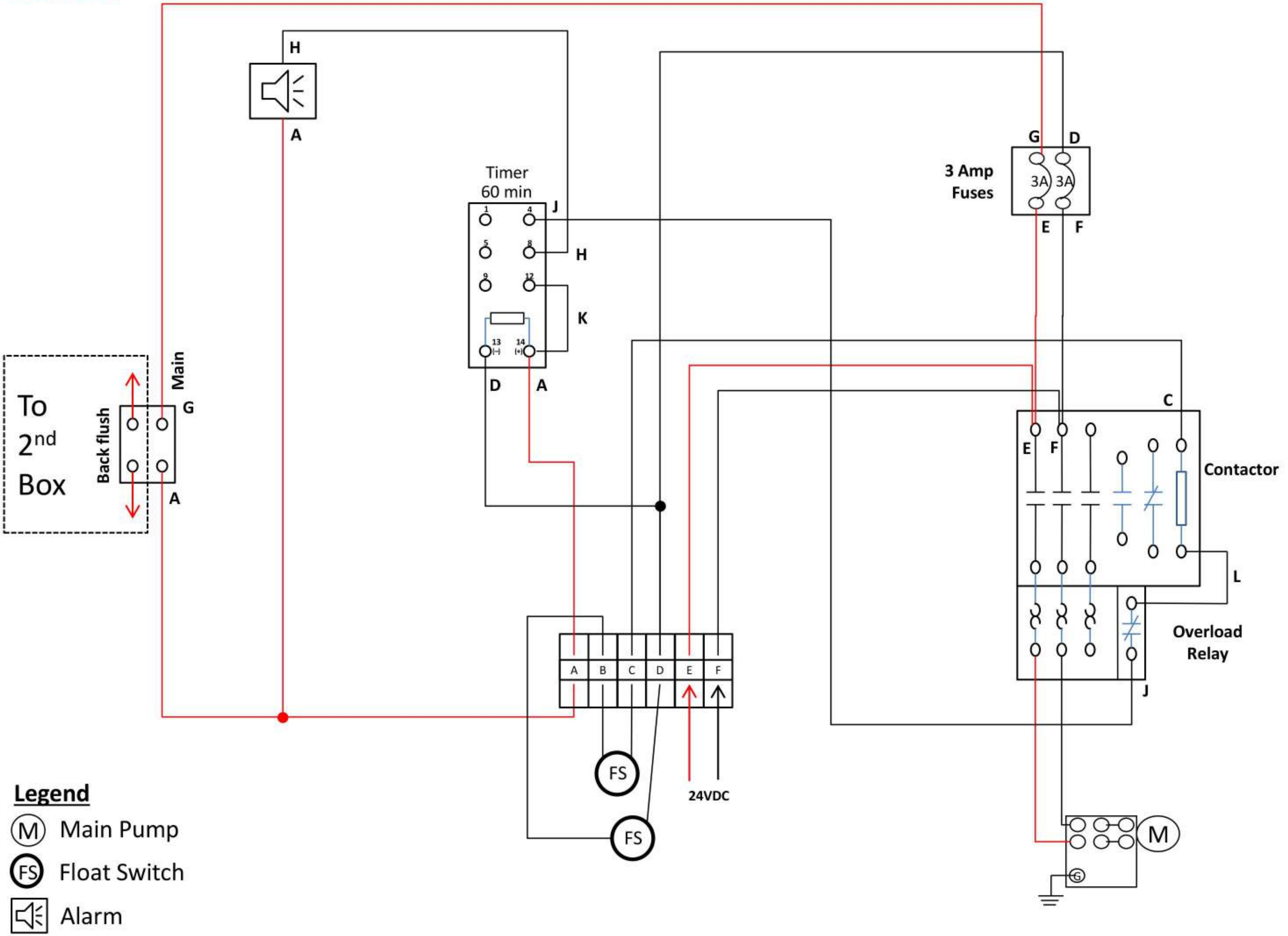
Blowers dispense 100% oil-free air for clean operation with less maintenance. An internal (unless noted) muffler is included for reduced noise. Blowers have an aluminum housing (except for model 9960K66, which is cast iron). Rated for continuous operation, they are powered by a motor that operates on 60 Hz. They must be hardwired.

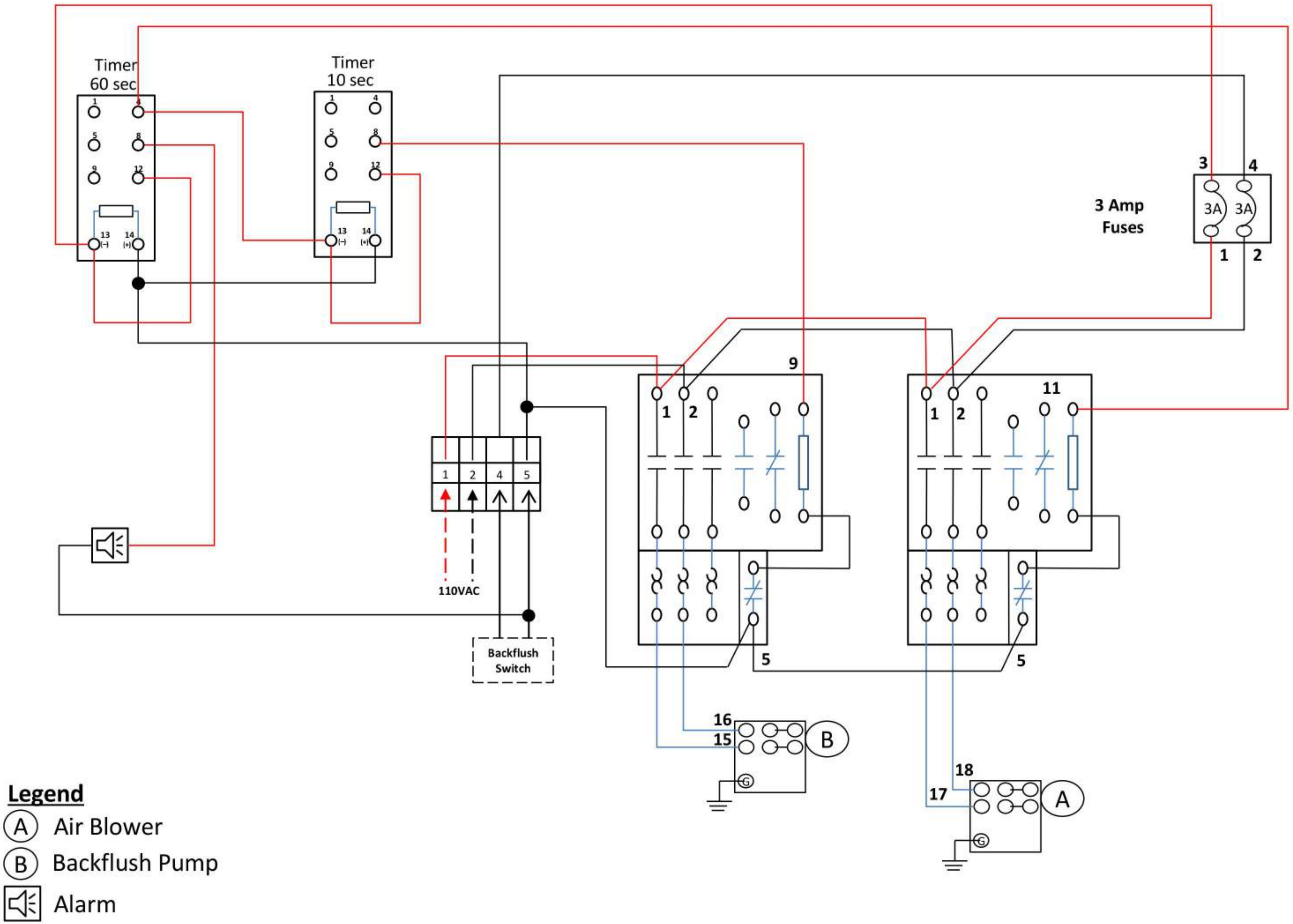
Note: You must use clean, filtered air (free of debris) with these blowers. We strongly recommend an air intake filter and a relief valve (see below for relief valves for two-stage blowers or see our offering of relief valves for single-stage blowers) to protect against damage from overheating.

Single-Stage Blowers—Standard models have NPT female inlet and outlet ports. Motors are UL recognized, CSA certified, and CE approved.

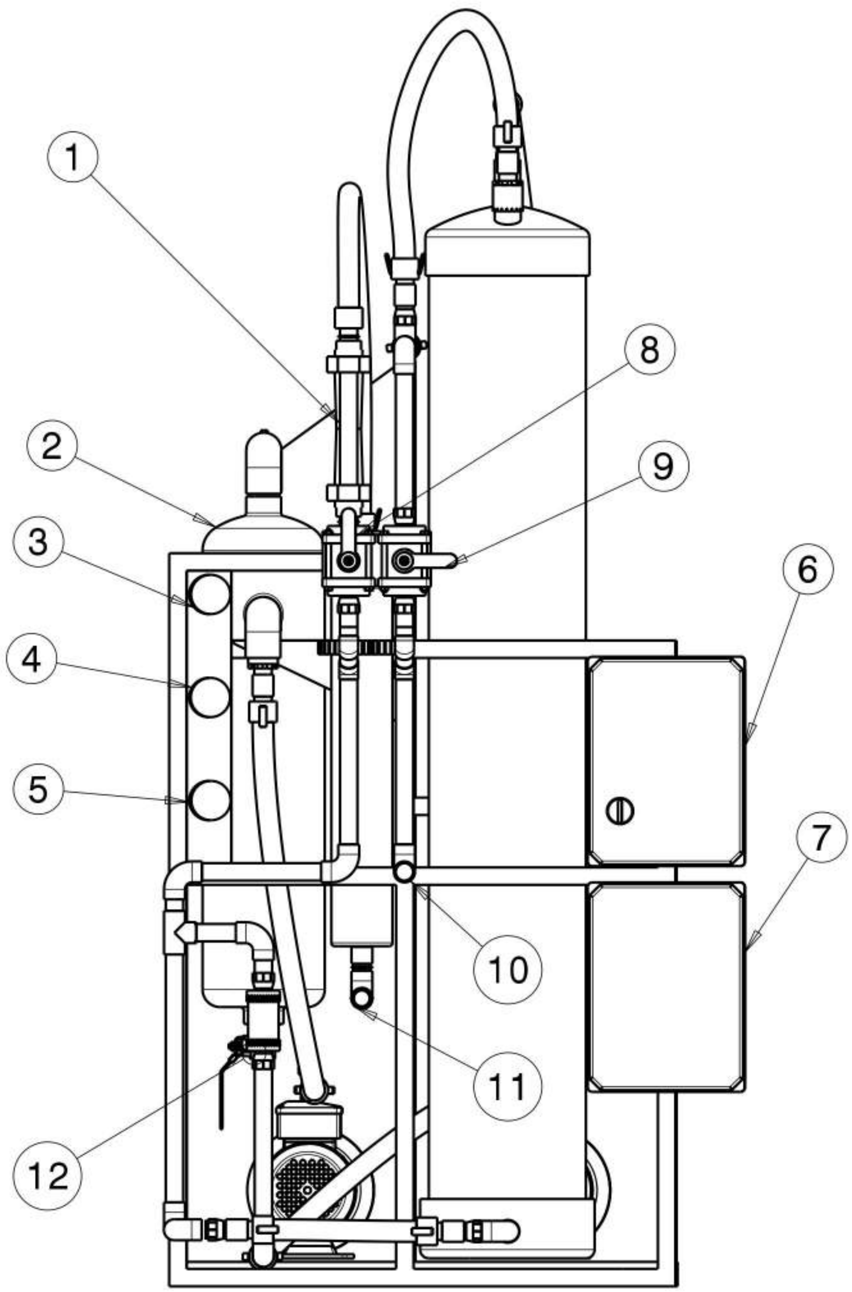
Air Flow, cfm at 0 psi	52
Maximum Pressure	
psi	2.1
Inch of Water	55
Maximum Vacuum	
Inch of Mercury	3.7
Inch of Water	50
Motor	
hp	1/2
Full Load Amps	5.6/3.0-2.8
Inlet/Outlet Size, NPT	1 1/4"
Overall Size	
Length	11"
Width	9.8"
Height	10.2"
dB Rating	70
Additional Specifications	Standard Single-Stage Blowers 115/208-230V AC, Single-Phase Motor

Main BOX


H
A
Timer
60 min
1
4
J
5
8
H
9
12
K
13
14
D
A
G
D
3 Amp
Fuses
3A
3A
E
F
To
2nd
Box
Back flush
Main
G
A
C
E
F
Contactor
L
Overload
Relay
J
A
B
C
D
E
F
FS
FS
24VDC
M
G
Legend
M Main Pump
FS Float Switch
Alarm



Backwash BOX 110VAC



Part #	Description
1	Flow Meter(sheet 7)
2	Helix Filter(sheet 3)
3	Helix Outlet Pressure Gauge
4	UF Inlet Pressure Gauge
5	UF Outlet/Backflush Pressure Gauge
6	Control Box 1
7	Control Box 2
8	2 Way Ball Valve
9	2 Way Ball Valve
10	Backflush Outlet
11	Clean Water Outlet
12	Check Valve

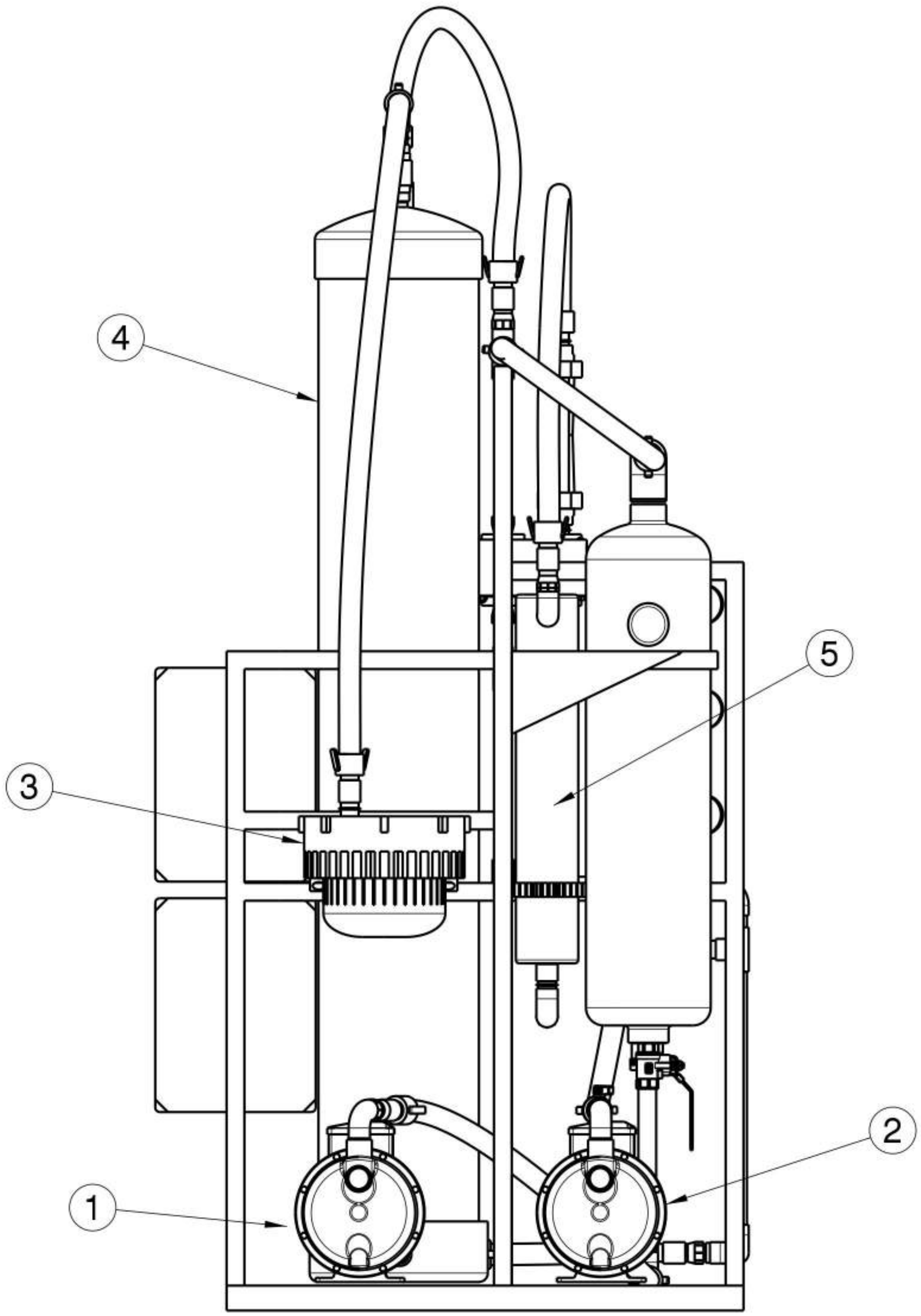
EMBRY RIDDLE AERONAUTICAL UNIVERSITY
DAYTONA BEACH, FLORIDA

SIZE:	DATE:	SCALE:	
A	08/07/13	1:11	Project Haiti

DRAWN BY: SHAVIN PINTO

DRAWING TITLE: Major Components

SHEET: 1/7



Part #	Description
1	Backflush Pump
2	Normal Flow Pump (sheet 5)
3	Blower
4	UF Filter(Sheet 4)
5	UV Filter(sheet 7)

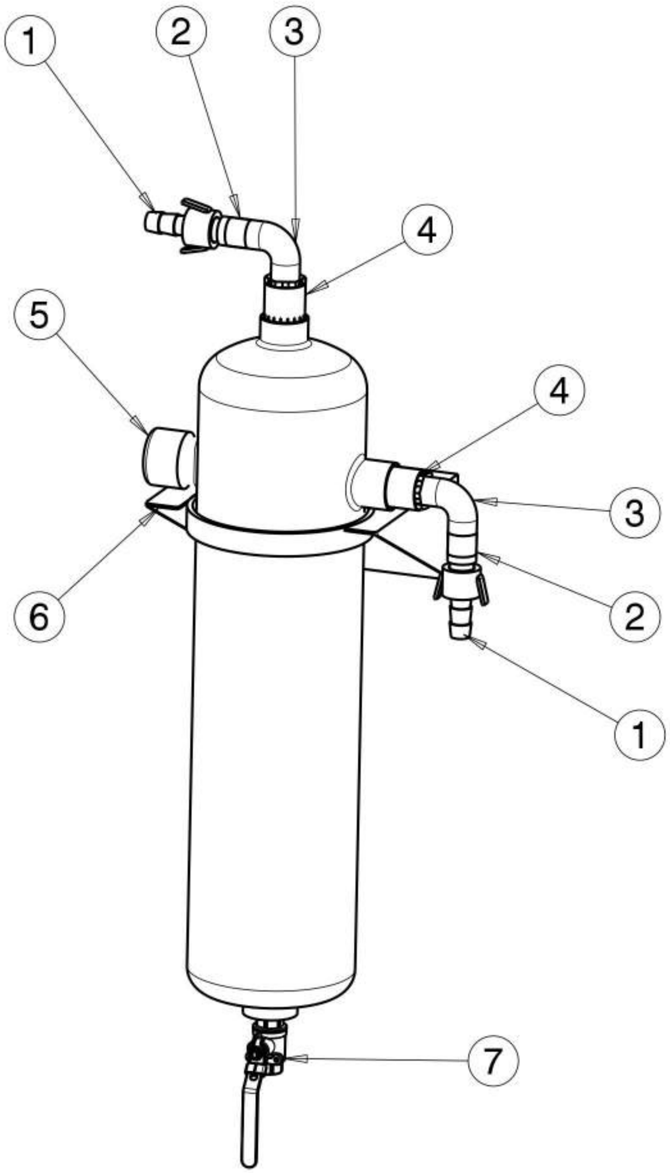
EMBRY RIDDLE AERONAUTICAL UNIVERSITY
DAYTONA BEACH, FLORIDA

SIZE:	DATE:	SCALE:	
A	08/07/13	1:10	Project Haiti

DRAWN BY: SHAVIN PINTO

DRAWING TITLE: Major Components

SHEET: 2/7



Part #	Description
1	1"Female Coupler X Hose Shank
2	1"Male adpt X FNPT
3	1"Elbow - MNPT X PVC
4	1" PVC X 1.5"FNPT
5	1.5" End Cap
6	Helix Mount Bracket
7	2" X 1.5" Adapter
8	3/4" Flush Port Valve

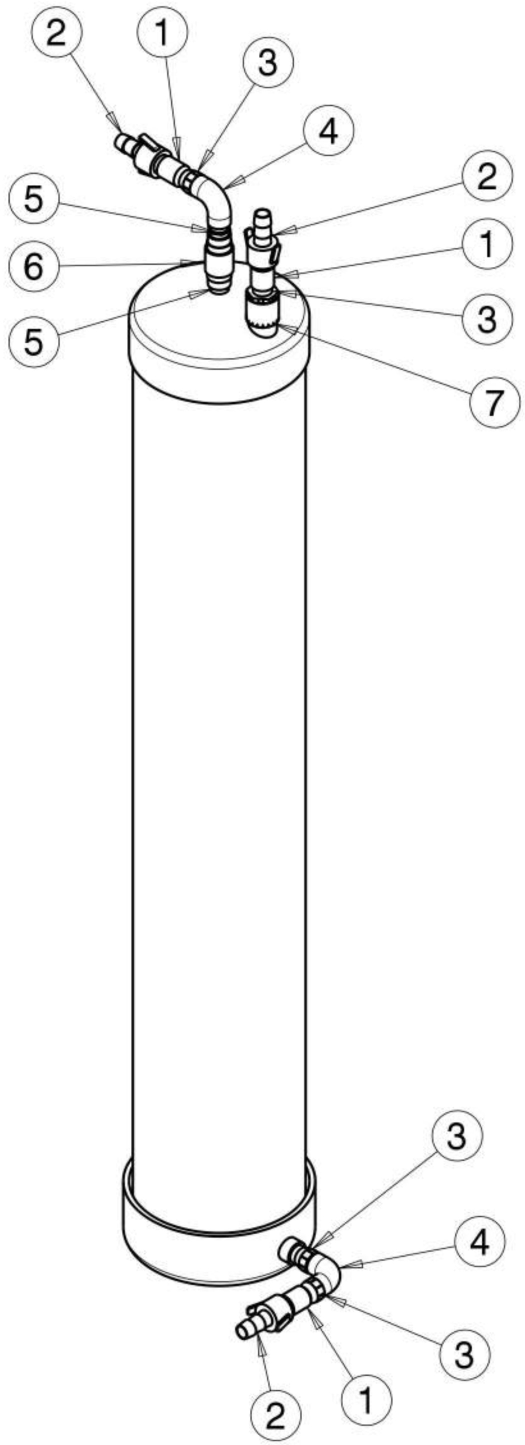
EMBRY RIDDLE AERONAUTICAL UNIVERSITY
DAYTONA BEACH, FLORIDA

SIZE:	DATE:	SCALE:	
A	08/07/13	1:9	Project Haiti

DRAWN BY: SHAVIN PINTO

DRAWING TITLE: Helix Filter Connections

SHEET: 3/7



Part #	Description
1	1"Female Coupler X Hose Shank
2	1" Male Adpt X FNPT
3	1" PVC X MNPT
4	1" Elbow - PVC X FNPT
5	1" MNPT Nipple
6	1" FNPT Check Valve
7	1.5" X 1" Reducer

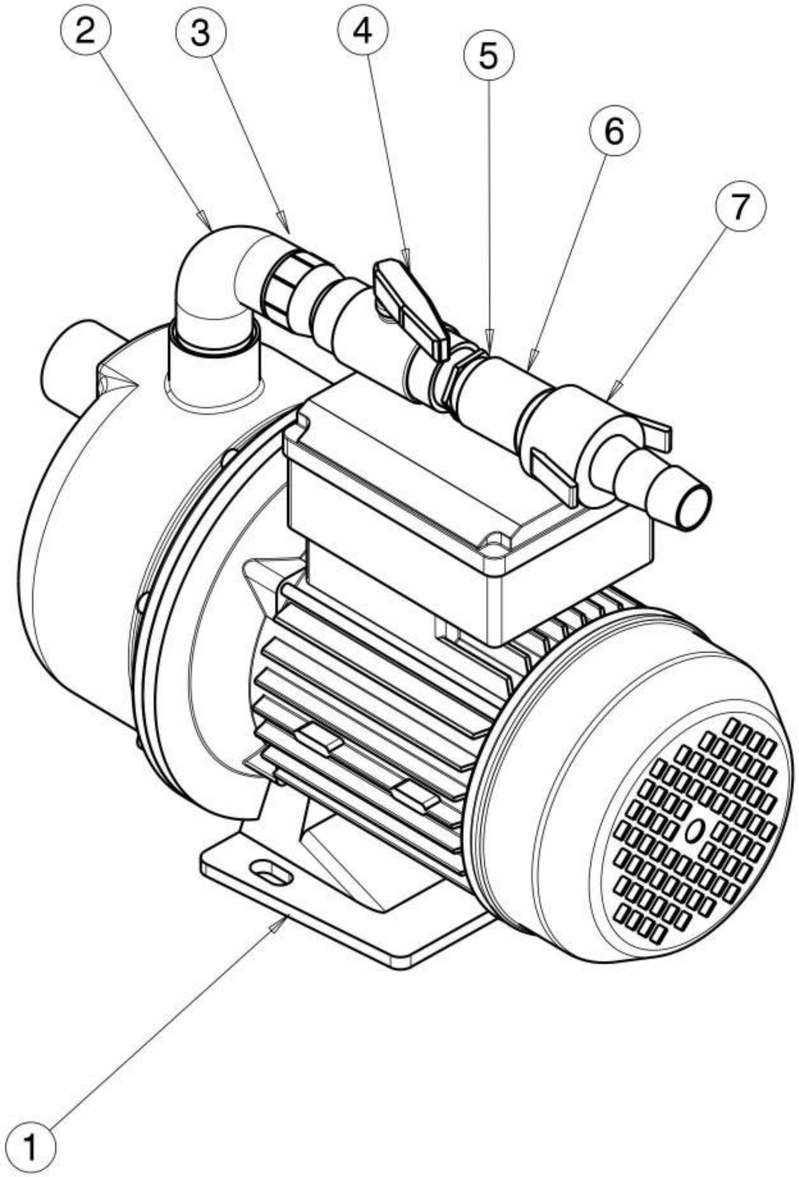
EMBRY RIDDLE AERONAUTICAL UNIVERSITY
DAYTONA BEACH, FLORIDA

SIZE:	DATE:	SCALE:	
A	08/07/13	1:8	Project Haiti

DRAWN BY: SHAVIN PINTO

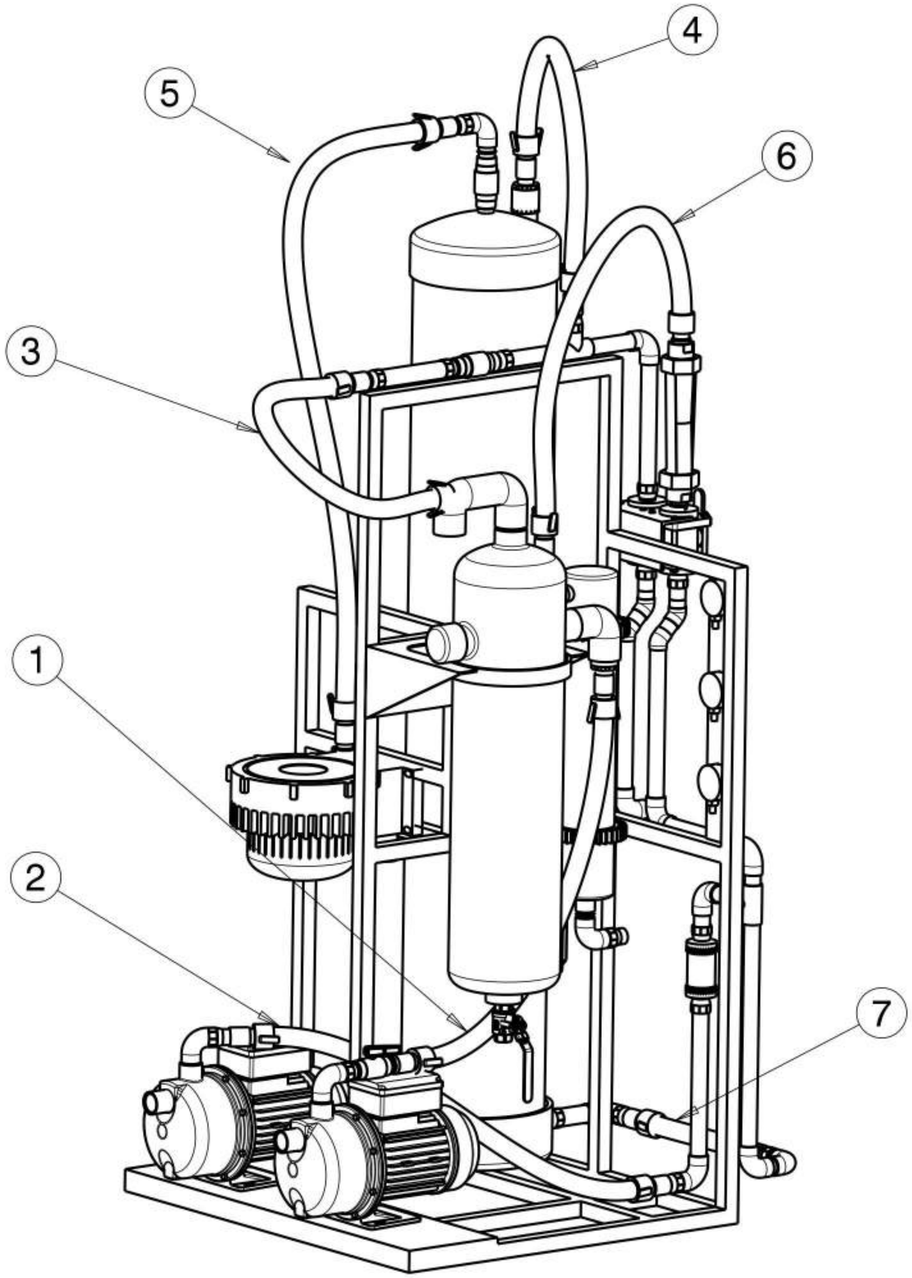
DRAWING TITLE: UF Filter Connections

SHEET: 4/7



Part #	Description
1	Gianneschi- Ecoinox 2
2	1" Elbow- PVC X MNPT
3	1" PVC X MNPT
4	1" Ball Valve
5	1" MNPT Nipple
6	1"Female Coupler X Hose Shank
7	1" Male Adaptor X FNPT

EMBRY RIDDLE AERONAUTICAL UNIVERSITY DAYTONA BEACH, FLORIDA			
SIZE: A	DATE: 08/07/13	SCALE: 1:4	Project Haiti
DRAWN BY: SHAVIN PINTO			
DRAWING TITLE: Pump Connections			SHEET: 5/7



Part #	Description
1	Inline Flow-1"
2	Backflush Flow-1"
3	Helix Filter Outlet-1"
4	UF Water Inlet-1"
5	UF Air Inlet-1"
6	UV Water Inlet -1"
7	UF Water Outler-1"

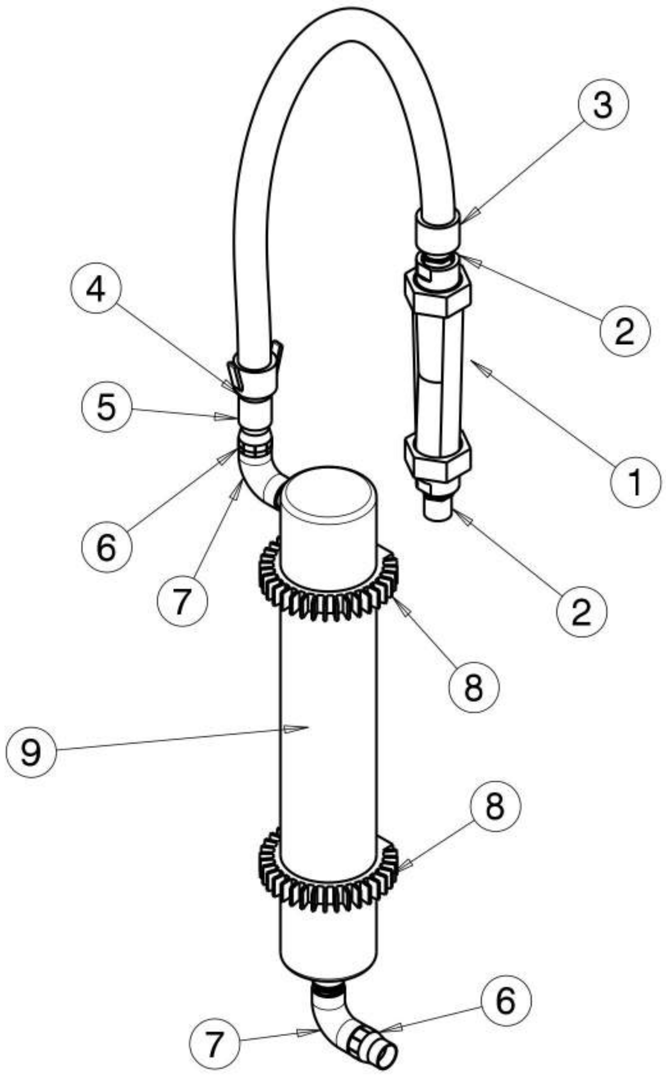
EMBRY RIDDLE AERONAUTICAL UNIVERSITY
DAYTONA BEACH, FLORIDA

SIZE:	DATE:	SCALE:	
A	08/07/13	1:12	Project Haiti

DRAWN BY: SHAVIN PINTO

DRAWING TITLE: Flexible Hose Connections

SHEET: 6/7



Part #	Description
1	Flow Meter
2	1" MNPT Nipple
3	1" Hose Shank X FNPT
4	1"Female Coupler X Hose Shank
5	1"Male adpt X FNPT
6	1" PVC X MNPT
7	1"Elbow - FNPT X PVC
8	UV Bracket
9	UV Filter

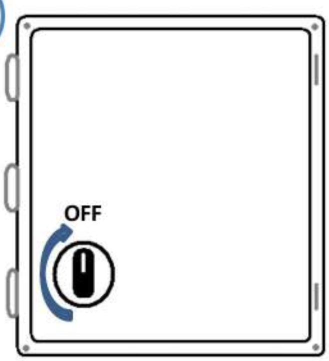
EMBRY RIDDLE AERONAUTICAL UNIVERSITY DAYTONA BEACH, FLORIDA			
SIZE: A	DATE: 08/07/13	SCALE: 1:7	Project Haiti
DRAWN BY: SHAVIN PINTO			
DRAWING TITLE: UV Filter & Flow meter			SHEET: 7/7

Appendix E

Project Haiti 2013 Quick Start Guide

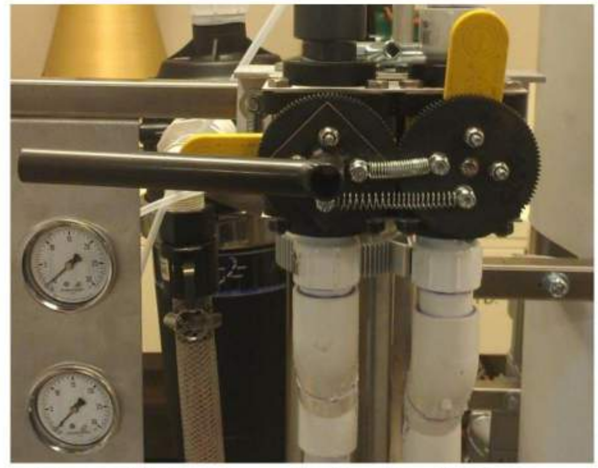
Back flush Operation Quick Start Guide

1



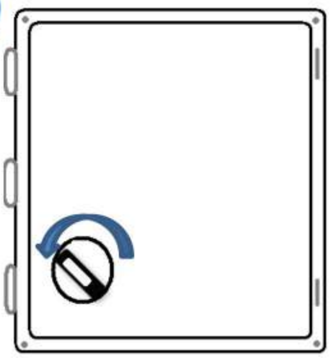
Turn switch 'OFF'

2



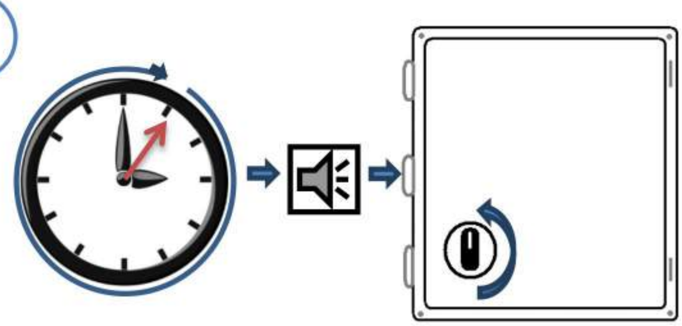
Turn Metal handle to the Left

3



Turn switch left to 'Back flush'

4

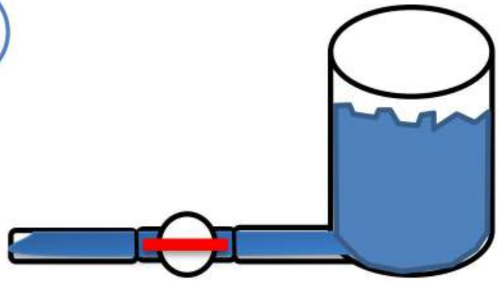


After 1 minute the alarm will activate,
then turn switch to 'OFF'

Normal Operation

Normal Operation Quick Start Guide

1

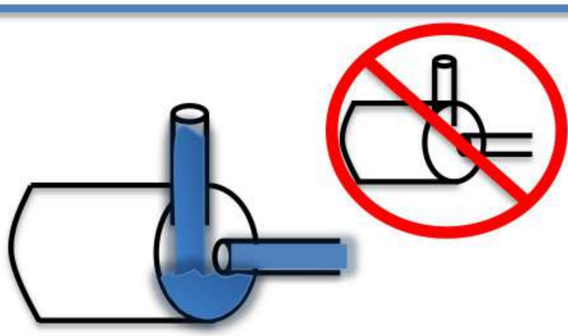


Ensure all valves from water tank are open. Make sure that all hoses are in the proper place and secured

2

Turn on the two 15 Amp solar circuit breakers and Charge Controller

3

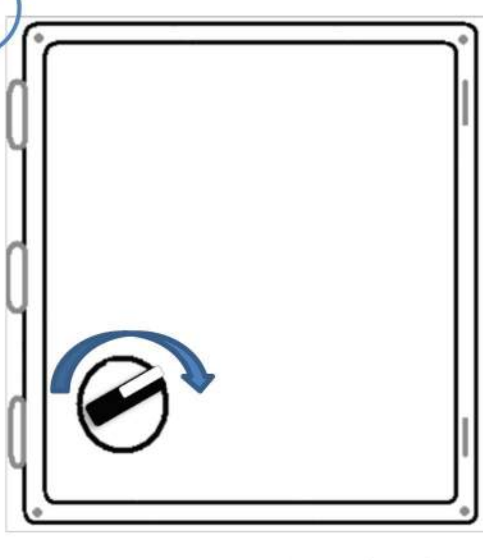


Ensure that pumps are primed (have water in them)
*See user's manual on how to prime pumps

4

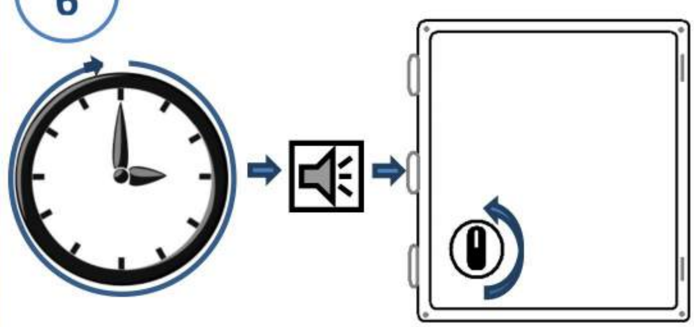
Turn metal handle down

5



Turn switch right to 'ON'

6



After 1 hour the alarm will activate, then turn switch to 'OFF'

Appendix F

Bacteria Test Kits User Manual

Print Instructions

PROFESSIONAL BACTERIA IN WATER TEST KIT

According to the Environmental Protection Agency (EPA), total coliform and e. coli bacteria testing is recommended to indicate the presence of organisms that can cause deadly diseases.

WHAT IS BACTERIA?
Bacteria are microscopic, one-celled organisms usually classified as plants (in a division called fungi). Bacteria typically originates in human and animal wastes and can enter a water supply from septic tank drainage, sewage, feedlot manure or direct drainage of surface runoff into wells. Bacterial contamination remains the most common water quality problem for individual (private wells) and small community public systems (under 1,000 service connections).

HOW DO YOU COME IN CONTACT WITH BACTERIA?
Fecal coliform bacteria are mostly found in drinking water that comes from private wells and small water systems. This is partly because private water supplies, small rural public water supplies and private wells are not required, by law, to be tested. Every time you drink water from one of these sources, you may be exposed to harmful levels of bacteria, which can pose immediate threat to your health. Families drinking non-chlorinated water(such as from an underground well) and apartment dwellers roof-top wood storage tanks are especially susceptible to bacterial contamination. Home water treatment devices utilizing GAC (Granular Activated Charcoal) as a singular filtering device may also become a breeding ground for bacteria.

WHAT CAN BACTERIA DO TO YOU?
Fecal coliform bacteria in drinking water can lead to diseases such as typhoid fever and cholera, though these diseases are rare in the United States. Fecal coliform bacteria contamination can also lead to infectious hepatitis and dysentery, which are more common. Some experts believe that exposure to high levels of bacteria in drinking water can also make infants more susceptible to the toxic effects of nitrates in drinking water. Symptoms associated with bacterial contamination include digestive problems, fever, nausea, diarrhea and cramps.

HOW DO YOU FIND OUT IF YOU HAVE A BACTERIA PROBLEM?
To find out if bacteria is a problem in your water, you must test. The PRO-LAB Professional Bacteria in Water Test Kit offers two (2) types of analytical methods. The first method simply involves counting the number of colonies that are growing on the petri dish. The second method (optional) requires send- ing the petri dish to PRO-LAB for a more detailed analysis, which will identify the bacteria present in your water.

COMPLETE DIRECTIONS INSIDE
KEEP OUT OF REACH OF CHILDREN
CONTENTS
Petri dish
Bacteria medium
Calibrated pipette/dropper
Information form

IF YOU HAVE ANY QUESTIONS OR
COMMENTS PLEASE CALL (800) 427-0550
Or visit us on the Internet at: www.prolabinc.com

"Home Safety Test Kits"
WESTON, FLORIDA, 33326
MADE IN U.S.A.

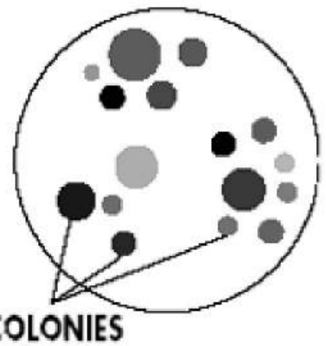
The PRO-LAB Bacteria in Water Test Kit (patented) is designed to detect dangerous bacteria in your drinking water. The test kit offers two (2) types of analytical methods. Method 1 (self-test) simply involves counting the num- ber of colonies that are growing on the petri dish 48 hours after sampling and then comparing the value with the enclosed chart. Method 2 (optional) involves sending the petri dish to PRO-LAB for a more detailed analysis, which will identify the type of bacteria present in your water. Note: all sampling methodologies are subject to the occurrence of false negative and false positive results.

DIRECTIONS
1.Remove petri dish from the plastic bag and lay it on a level surface with the lid side up. **DO NOT TOUCH** the inside of the petri dish or expose it to the outside until you are ready to use it.
2. Completley fill the 1ml pipette/dropper with sample water, place the test sample water into the bacteria medium bottle. Recap the bottle and invert twice to mix the sample water with the medium. Do not shake.
3. Lift the lid of the pretreated dish and pour the mixed bacteria medium into the dish bottom. Replace the lid and swirl gently until the bottom is completely covered. Allow to harden for 1 hour on a level service.

4. Incubate the dish at room temperature for 48 hours.

DETERMINING RESULTS USING METHOD 1 (SELFTEST)

After incubation period of 48 hours, count the number of colonies (dots on the petri dish). Bacteria colonies appear solid-looking. The colonies may be very small or may spread considerably. They may be colorless, whitish, or a vari-ety of colors. Refer to the chart below to determine the results of your test. Recheck the dish at 72 hours to be sure that no slow growing bacteria where overlooked.

PETRI DISH	# OF COLONIES	GUIDELINE
	0-5	Typically indicates clean water. Retest in six (6) months
	More than 5	Typically indicates water with abnormal amounts of bacteria. Water sanitation or filtration recommended. Analytical Method 2 also recommended.

ANALYTICAL METHOD 2 (OPTIONAL)

1. After conducting the self test, replace the lid and seal around the edges of the petri dish with tape (clear, electrical duct tape).
2. Completely fill out the information form (analysis can not be conducted unless you submit all of the information requested)

STANDARD LAB RESULTS

The PRO-LAB Professional Bacteria in Water Test Kit requires a $30 lab fee. Place the petri dish in a padded envelope or box along with the information form, and a check, money order (made payable to PRO-LAB) or a credit card voucher for $30 (Visa, MasterCard, AMEX or Discover only). Mail immediately (within 24 hours of replacing the lid). Send the sample to PRO-LAB, 1675 N. Commerce Parkway, Suite 100, Weston, FL 33326. Within two weeks after PRO-LAB has received your sample, we will send you an easy to read evaluation indicating the exact count and type of bacteria present.

EXPRESS FAX SERVICE

Express Service is available for an additional $15. In order to use the express service, you must send the sample, the information form and proper payment to PRO-LAB using an overnight shipping company such as Federal Express, Airborne Express or UPS. Send the sample to PRO-LAB, 1675 N. Commerce Parkway, Suite 100, Weston, FL 33326. (An express sample can only be received Monday - Friday). Within 72 hours of our receipt you will receive your faxed results.

FOR QUESTIONS OR MORE INFORMATION CALL 1-800-427-0550

CREDIT CARD VOUCHER

☐ STANDARD LAB RESULTS ($30) $30
☐ EXPRESS FAX SERVICE ADD ($15) $
TOTAL $

Make Checks Payable to PRO-LAB

☐ CHECK ☐ MONEY ORDER ☐ CREDIT CARD

PRO-LAB **BACTERIA IN WATER TEST KIT CREDIT CARD VOUCHER (VISA, MASTERCARD, AMEX & DISCOVER ONLY)**

Name (as it appears on card)

Street Address

City/State/Zip

Credit Card # Expiration Date

Amount $ Phone

Signature Date / /

1675 N. Commerce Parkway, Suite 100 - Weston, FL 33326

INFORMATION FORM

Name

Street Address

City State Zip

Phone ( ) Fax for Express Service Only ( )

BACTERIA SAMPLE

Date of Sample

Where was the sample taken from?

☐ House ☐ Apartment ☐ Office ☐ Other:

Age of house (or Building) in years:

Faucet Location:

Is their a purification system ☐ *Yes* ☐ *No* *If yes what type:*

Water Source: ☐ *Muncipal* ☐ *Spring* ☐ *Well* *Well Depth*

For Lab Use Only:

Date Sample Received Time Received by

Close Window

Bacteria, Hydrogen Sulfide Producing

DOC316.53.01197

Presence/Absence (P/A) Method **Methods 8506**

Pathoscreen™ Medium

Scope and Application: For the detection of Salmonella, Citrobacter, Proteus, Edwardsiella and Klebsiella (some spp.) in drinking water, surface water and recreational water

Test preparation

PathoScreen Medium

PathoScreen Medium detects the presence of hydrogen sulfide-producing bacteria including *Salmonella, Citrobacter, Proteus, Edwardsiella and* some species of *Klebsiella*. The sterilized powder medium is a reliable medium for monitoring drinking water systems in developing tropical countries, in remote field locations and in disaster or emergency situations.

PathoScreen Medium is dehydrated, sterilized and packaged in powder pillows. Powder pillows are available for both Presence/Absence (P/A) and Most Probable Number (MPN) testing. Each powder pillow contains enough medium for one test. The medium is shipped with a Certificate of Analysis and has an expiration date printed on the label.

For P/A testing, add one P/A powder pillow to a 100-mL sample.

Before starting the test:

Incubate samples 24–48 hours between 25–35 °C, 77–95 °F. (30 °C, 80 °F is considered optimal.)
PathoScreen Medium has a detection sensitivity of 1 CFU/100 mL.
Disinfect the work bench with a germicidal cloth, dilute bleach solution, bactericidal spray or dilute iodine solution.
Wash hands thoroughly with soap and water.

PathoScreen medium P/A pillows, method 8506

1. Wash hands thoroughly with soap and water.

2. Collect 100 mL of sample in a sterile sample container.

3. Swab the end of the PathoScreen Medium P/A Pillow with alcohol and aseptically cut it open with clippers. Add pillow contents to the 100 mL sample.

4. Place the bottle in a location with a constant temperature between 25–35 °C for 24–48 hours.

If an incubator is available, incubate the sample at 30 ±0.5 °C for 24 to 48 hours.

5. Note the reaction after 24 hours of incubation.

If the temperature varies significantly, incubation may be extended an additional day.

6. Record the results. (See the *P/A results* table.)

Dispose of all completed tests appropriately. Refer to a current MSDS and local regulations.

Table 437 P/A results

Hydrogen sulfide producing bacteria			
Test Results	**Positive**	**Negative**	**Follow-up**
Color changes from yellow to black	X		
Black precipitate forms	X		
No color change		X	Incubate additional 12–24 hours and re-evaluate. If there is no color change, record as negative.

Consumables and replacement items

Required reagents

Description	Unit	Catalog number
PathoScreen™ Medium, P/A Pillows, 100-mL sample	50/pkg	2610696

Dilution water—media, reagents and apparatus

Description	Unit	Catalog number
Bottle, polysulfone, autoclavable (for preparing buffered dilution water)	12/pkg	2245300
Buffered Dilution Water, sterile, 99-mL[1]	25/pkg	1430598
Dechlorinating Reagent Powder Pillows	100/pkg	1436369

[1] Buffered Dilution Water is prepared with magnesium chloride and potassium dihydrogen phosphate.

Required apparatus

Description	Unit	Catalog number
Autoclave, Automatic, 120 VAC	each	2898600
Clippers, large	each	2065800
Contaminated Items Bags	200/pkg	2463300
Germicidal Cloth	50/pkg	2463200
Incubator, Culture, 120 VAC	each	2619200
Incubator, Culture, 220 VAC	each	2619202
Sampling Containers		
Sampling Bags, Whirl-Pak with dechlorinating agent, 180-mL	100/pkg	2075333
Sampling Bottles, autoclavable	6/pkg	2324333
Sampling Bottles, autoclavable	48/pkg	2324373
Sampling Bottles, sterilized, 100-mL fill-to line	12/pkg	2495012
Sampling Bottles, sterilized, 100-mL fill-to line	50/pkg	2495050
Sampling Bottles, sterilized, 100-mL fill-to line, with dechlorinating agent	12/pkg	2599112
Sampling Bottles, sterilized, 100-mL fill-to line, with dechlorinating agent	50/pkg	2599150

Optional media and reagents

Description	Unit	Catalog number
Bottle, polysulfone, autoclavable (for preparing buffered dilution water)	12/pkg	2245300
Magnesium Chloride and Potassium Dihydrogen Phosphate Powder Pillows	25 of each	2143166
Peptone Powder Pillows, 1-g	30/pkg	2142964
Sterilization Indicator, Sterikon®	15/pkg	2811115
Sterilization Indicator, Sterikon	100/pkg	2811199
Bags, Whirl-Pak®, without dechlor 207 mL	100/pkg	2233199
Bags, Whirl-Pak, without dechlor 720 mL	10/pkg	1437297

FOR TECHNICAL ASSISTANCE, PRICE INFORMATION AND ORDERING:
In the U.S.A. – **Call toll-free 800-227-4224**
Outside the U.S.A. – **Contact the HACH office or distributor serving you.**
On the Worldwide Web – **www.hach.com**; E-mail – **techhelp@hach.com**

HACH COMPANY
WORLD HEADQUARTERS
Telephone: (970) 669-3050
FAX: (970) 669-2932

Edition 7